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THE RHEOTROPISM OF ROOTS.[1]

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(WITH FIFTEEN FIGURES)

A. INTRODUCTION.

I. HISTORICAL REVIEW.

THE first author to write of the influence of streaming water in directing plant movement was Strasburger,[2] who worked with the creeping plasmodia of the Myxomycetes. Several years later Stahl[3] devoted some time to the consideration of the same subject. Jönsson,[4] however, the year before Stahl's paper appeared, published the first research on the behavior of roots in a stream of water. Jönsson used seedlings of *Zea mays*, *Triticum vulgare*, and *Secale cereale*, finding both primary and secondary roots bending their tips against the stream of water, attaining finally the horizontal position, no matter in what direction the roots were placed when first immersed. The author states that a similar result could be obtained with the roots of other species of plants, but he does not say what other plants he

[1] XXXIII. Contribution from the Botanical Laboratory of the University of Michigan.

[2] STRASBURGER: Studien über das Protoplasma. Jenaisch. Zeitsch. **10**: 406. 1876.

[3] STAHL: Zur Biologie der Myxomyceten. Bot. Zeit. **42**: 145. 1884.

[4] JÖNSSON: Der richtende Einfluss strömenden Wassers auf wachsende Pflanzen und Pflanzentheile (Rheotropismus). Ber. Deutsch. Bot. Gesells. **1**: 512. 1883.

used, if any. Jönsson suspended his seedlings with their roots immersed in water conducted from a hydrant through a trough.

In 1896, I read before the American Association for the Advancement of Science a preliminary account of extensive experiments on the rheotropism of roots of seedlings. An abstract of this paper was published the same year in the BOTANICAL GAZETTE,[5] as well as in the *Proceedings* of the American Association for the Advancement of Science, and was briefly reviewed in the *Botanischer Jahresbericht;* yet it seems wholly to have escaped the attention of the two authors soon to be mentioned. In the preliminary account just cited, seventeen species of plants were reported, eight of them showing positive rheotropism, and nine showing no response to the streaming of the water. It was shown that definite relations exist between velocity of flow and response, that the latent period is influenced by various factors of the environment, that many roots are not responsive to a stream of water, that all roots which did respond were positive, that there are various degrees of sensitiveness in different species. Some attention was given to the nature of the stimulus, and it was suggested that it might be found to be pressure.

Very recently two authors have published papers on the subject of rheotropism. Berg[6] used the same apparatus that Jönsson employed, and another consisting of a basin of water in which he revolved seedlings fastened to a disk. By these means he found the roots of eleven plants to be positively rheotropic, while the root of *Glycine hispida* gave no response, though only three roots of the last species grew suitably for record. He devised a still better apparatus for securing streaming water; this consisted of a basin, to the water in which was given a rotary motion by a jet of water discharged in the basin in a tangential direction. Berg found the latent period of several roots at definite temperatures, and noted that the rheotropic curve began in the third or fourth millimeter zone from the apex of the root.

[5] NEWCOMBE: Rheotropism and the relation of response to stimulus. BOT. GAZ. **22**: 242. 1896; Proc. Amer. Ass. Adv. Sci. 1896; Bot. Jahresb. **24**[1]: 74. 1896.

[6] BERG: Studien über Rheotropismus bei den Keimwurzeln der Pflanzen. Lunds Universit. Årsskr. **35**[2]: no. 6. 1899.

Juel[7] made use of the same apparatus that I had described in my abstract in 1896 — a revolving basin of water in which the roots of seedlings were immersed. He worked with only three plants, *Zea mays*, *Vicia faba*, and *Vicia sativa*. The first two were found unsatisfactory, being irregular in their response, while the third was used for most of the results recorded. All three species were found to be positively rheotropic. No certain evidence for negative curving was found. The positive response for *Vicia sativa* was shown in velocities of current from 36^{cm} per second down to 0.3^{mm} per second. The maximum and minimum limits of velocity were not fixed. Juel experimented also with the location of the sensitive area, covering some root tips with collodion caps and decapitating some roots. In both cases he obtained responses in the streaming water, and concludes that the whole of the growing zone is sensitive ; whether the root-tip is sensitive was not determined. As to the nature of the stimulus inducing rheotropic bending, Juel could not decide. When he placed thin cylinders of collodion over his roots, the roots curved as before. He concludes that the stimulus may be pressure, but suggests that the collodion may have allowed a sufficient stream of water to pass through to give the same stimulus as when the root is naked.

It will be seen from the foregoing narration of work accomplished that there are various questions connected with rheotropism still unanswered. Some of these questions will be dealt with in the following pages. Especially will attention be given to the distribution of rheotropism among phanerogams, the sensitiveness of roots other than primary, the sensitiveness of roots of older plants, the relation of response to velocity of current, the latent period, the localization of the sensitive area, and the nature of the stimulus.

II. METHODS.

The majority of plants used in these experiments were seedlings. The seeds were planted in white pine (*Pinus Strobus*)

[7] JUEL : Untersuchungen über den Rheotropismus der Wurzeln. Jahrb. Wiss. Bot. **34** : 507. 1900.

sawdust. It was found that any other sawdust at hand would not give straight roots with several of the species. When the seedlings had attained a suitable length, they were removed from the sawdust, fastened to bars of white pine, and the bar was then suspended with the roots immersed in filtered tap-water. The method of fastening the seedlings to the wooden bar is so simple and so preferable to the common practice of pinning, that it may be worth while to illustrate it with *fig. 1*, and to detail it here. A bar of wood differing in diameter according to the size of the seedlings used is clamped in a vise. Two strips of heavy blotting paper are cut the same length and width of the wooden bar. Next, these two strips are dipped in water, and then laid, one covering the other, on the upper side of the wooden bar, and a rubber band is slipped on over one end of wood and blotting paper. The upper strip of blotting paper is raised with the fingers of one hand, while with those of the other a seedling is inserted between the two strips of paper and deposited close up to the rubber band. The upper strip of paper is then lowered upon the other, another rubber band slipped on, so that the seedling is held between the two pieces of blotting paper by two rubber bands, one on each side. The upper piece of paper is again raised, another seedling inserted, and so on till the bar is full.

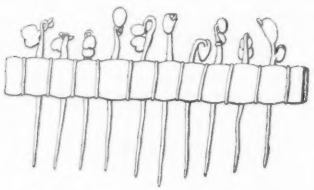

FIG. 1.—Seedlings of *Raphanus sativus*, illustrating the method of fastening to a bar of wood with blotting paper and rubber bands.

The great advantage of this method of suspending seedlings is seen in its avoidance of all trouble from Sachs's[8] curvature. The epicotyl or hypocotyl is left free to carry out this curve without changing the direction of the root. The simplicity and rapidity of preparation commend this method for various kinds of experimentation besides rheotropism. For seedlings whose roots are to be immersed in water, the blotting paper will supply

[8] SACHS: Arbeit. Bot. Inst. Würz. 1:402.

a suitable amount of moisture, if it is allowed to touch the surface of the water. The wooden bar is wholly unobjectionable if of white pine. I have always taken the precaution of immersing these wooden bars for twelve or more hours in running water before using. I have tested a score of species of seedlings, and have never been able to discover any disturbance of growth having its source in the wood. A heavy bar of glass, with a plane surface for the seedlings might be substituted for the wood.

For many kinds of experiments in which roots are to be immersed in water, it is advisable, as here practiced, to allow the preparation to stand with the roots in water for twelve to twenty-four hours before beginning the experiment; for, with the seedlings of many plants, a few or many roots undergo curves or distortions when placed in water. In my experiments all roots which had deviated from the vertical direction were removed before the streaming of the water was begun.

In most of the experiments here recorded, a flow of water was secured by revolving glass basins full of water on horizontal klinostats and centrifuges. The centrifuges were turned for some experiments by water motors, and for others by an electric motor. The latter gave a constant rate of revolution, so that with it the effect of different velocities could be studied. The apparatus, except the motor, is shown in *fig. 2*. Juel states that in a similar revolving basin which he used, he found the current deviating from the tangential direction, due to the disturbing effect of the opposing roots. To overcome this difficulty he divided his large basin up into four concentric compartments by inserting glass dishes, one within the other. In the most of my experiments, I suspended my seedlings along but one diameter, while Juel suspended his along three diameters. There was more reason for irregular or cross-currents in his basin, therefore, than in mine. I have used basins subdivided into three concentric compartments, and others undivided, and obtained uniformly the same results with both. I made several tests by observing the movement of particles floating in my non-divided revolving basins, and assured myself that the flow as it met the roots was practically uniformly

tangential. To avoid the disturbing effect of the light and change of temperature, the experiments were, in most cases, conducted in a dark room whose temperature was regulated to a variation of less than 2°. The lagging of the current was tested empirically by suspended and immersed particles, and found in all parts of the basin to amount to less than 1 per cent. in velocities of less than thirty revolutions per minute. In the data given in this paper this small retardation will be neglected.

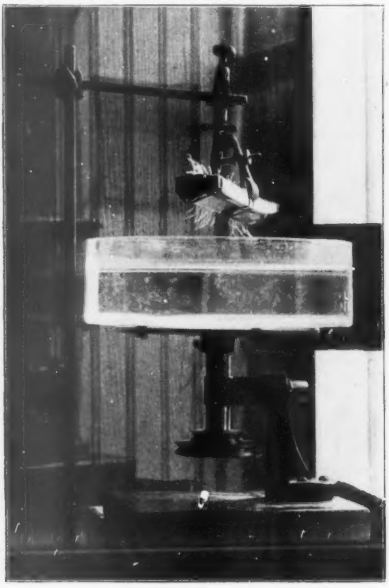

FIG. 2.—A centrifuge and a preparation of seedlings of *Brassica campestris* raised above the water. It will be seen that most of the roots show rheotropic curves of 45° or over, half of the curves being in one direction and half in the other, corresponding to the direction of the water-stream on opposite sides of the basin.

Besides the revolving basin, a narrow wooden trough was sometimes used. The water for this was obtained from a hydrant, and was passed through a gas-heater before being conducted to the trough. A few experiments were made during the night in a brook flowing through a deep ravine.

Various methods employed in the study of special parts of this problem would best not be given here; they will be found in the various sections of this paper.

III. GENERAL PHENOMENA.

The general appearance and progress of the phenomenon of rhetropism in roots are as follows: When plants rheotropically

sensitive have their roots immersed in a current of water of suitable velocity, the roots bend with a greater or less angle against the stream, thus opposing the mechanical effect of the streaming water and the response to gravitation. The angle of curvature in this rheotropic response, as in other phenomena of irritability, is in the growing zone, and there is a definite latent period and after-effect. The angle of curvature in sensitive plants ranges from a few to 90°, thus bringing the tip of the root into the horizontal position. Rheotropism of roots is not a general phenomenon, and great variation in the degree of response is displayed by different species.

B. RESULTS WITH SEEDLINGS.

I. DISTRIBUTION AMONG PHANEROGAMS.

1. *Plants unsuited to experiment.*

Everyone who has made any considerable number of water cultures with seedlings has learned that various species or varieties produce in water only badly contorted primary roots. Obviously such plants cannot be used to any great extent in the study of rheotropism. *Zea mays*, in the four varieties of field and sweet corn employed, showed itself to be practically worthless for experiment with primary roots. The variety of field corn used was a *Western dent;* and of sweet corn, the *White cob*, *Early Minnesota*, and *Old colony*. One hundred and twenty-four individuals of these four varieties were grown in water till the main roots were from a few millimeters to 5^{cm} in length, and none of them produced in still water 30 per cent. of straight roots. In many cases the tip of the primary root was lifted above the water; in others, the root pursued a zigzag course downward; while in others the direction was an irregular spiral.

It is worth noting that Jönssen and Berg for the main part of their work used this erratic *Zea mays*, and Juel employed it to some extent. All three authors, however, call attention to the large number of contorted roots formed. My own results teach that the relatively small number of straight-growing roots

of *Zea mays* (field and sweet corn) are feebly positively rheotropic.

Phaseolus vulgaris, *P. lunatus*, and *P. multiflorus* produce in water better roots than *Zea mays*, but still show a large percentage of contortion. It will be seen later on that these roots are not rheotropic.

Tropaeolum majus, *Pisum sativum*, *Vicia sativa*, and *Lathyrus odoratus* also produce many poor roots in water, though 40 per cent. to 80 per cent. will grow straight.

2. *Plants insensitive to a stream of water.*

Of the thirty-two species of plants tested for rheotropism, fourteen have shown themselves insensitive to the water-stream. These distribute themselves through nine families; while the rheotropic species number eighteen, and are distributed over six families. This result shows that rheotropism of roots is not a general phenomenon. In the narrative of experiments which is to follow, only those details will be given which are necessary to show the basis of the conclusions reached.

Three species of water plants, *Potamogeton perfoliatus*, *Elodea canadensis*, *Ranunculus aquatilis*, were brought under experiment, as follows: From vigorous individuals, apical portions were cut, 10^{cm} or more in length. These cuttings were secured in an upright position to thin glass rods, by tying with thread, and the glass rods were then fastened by rubber bands to a bar of wood 20^{cm} in length, which was suspended in the horizontal diameter of a suitable cylindrical glass aquarium containing water. The bar of wood was wholly above the water, and the lower parts of the glass rods with the plants were submerged. Several aquaria, thus prepared, were set in a south window, and the lower ends of the plants were screened from the direct rays of the sun. Within a week all plants had sent out several to many adventitious roots, the general direction of which was vertically downward. The preparations were then placed upon centrifuges, and the aquaria revolved, while the plants were held at rest in the vertical plane of a diameter. The glass rods and,

to a greater extent, the plants themselves, necessarily disturbed the flowing of the water. But the plants were not more than five in any aquarium, and hence were well separated from one another. Moreover, after the disturbance in passing one radial row of plants, the stream had a full semicircle in which to compose itself before meeting the other radial row. A practical test, made by suspending algal filaments to the roots and watching their trailing, showed that the roots were met by a stream with a constant direction.

Five plants of Elodea were used, and these produced eleven roots in all. Two roots were in streams of a velocity of 628^{cm} per minute, not allowing for the lagging; two in streams of 345^{cm} per min.; and one in a stream of 162^{cm} per min. The revolution continued without interruption for 60 hours, and the temperature of the water varied from 24° to 28°. These eleven roots showed considerable nutation, but none gave any curve in response to the stream, the resultant position of each root being vertical.

Of *Potamogeton perfoliatus* four plants were used. The total number of roots formed was 48. They grew well in streams ranging in velocity from 200^{cm} per minute to 628^{cm} per minute. Constant revolution was maintained for 56 hours in a temperature varying from 24° to 28°, but no curves resulted. The roots were wholly indifferent to the stream.

Ranunculus aquatilis was represented by four individuals, which developed ten roots in all. The revolution continued for 72 hours in a temperature of 24° to 28° in water with the roots in a stream velocity of 188^{cm} to 284^{cm} per minute. The roots showed considerable nutation, but no curves in response to the stream. The nutation, like that in Elodea, consisted of oscillation through an arc often of 45° on each side of the vertical, but in the resultant the roots advanced straight downward, elongating several centimeters during the course of the experiment. In order to clear away any question that may arise at this point as to the suitability of the velocity of stream employed, it may be said that all of the plants which have shown themselves

rheotropic have been sensitive to streams of the velocities given above.

From the results obtained with these three water plants, we may infer that rheotropism is not a general phenomenon with such plants. Possibly it may not be found in any water plant. It would seem to be of distinct disadvantage for such plants to be rheotropic in their roots. For only by insensitiveness to the flow of water can the roots the most quickly find the solid substratum.

Allium cepa was tested both in the bulb and in seedlings. The bulbs used were of the variety known as "multiplier." They were suspended so that the lower end dipped slightly into the revolving dish of water. Three periods of revolution were tried—9 hours, 24 hours, and 37 hours—with the temperature ranging from 16° to 23°, most of the time being above 20°. The velocities of flow ranged from 100^{cm} to 250^{cm} per minute. The number of roots growing well was twenty-eight, and these were most of them 2^{cm} long when the experiment began. In one of the three experiments eight roots bent positively, one negatively, and two grew vertically downward. In the two other experiments, one root bent negatively 90°, while the sixteen others grew in a vertical plane or showed no deviation caused by the current of water. It would thus seem that the roots from the bulb of this variety of the onion are either insensitive or at most but very slightly sensitive rheotropically. Twenty-three seedlings of the onion were tested in streams ranging from 75^{cm} to 600^{cm} per minute, there being continuous revolution for 38 hours, at a temperature of 23.5°. None deviated from the vertical direction, though all grew well.

Nasturtium officinale grows well with roots in water, all pursuing a remarkably straight course downward. Forty seedlings with roots 1^{cm} to 1.5^{cm} in length had their roots subjected to a continuous water stream for 45 hours, at a water temperature of 20.5° to 24.5°, velocity ranging from 100^{cm} to 900^{cm} per minute. All grew vigorously and vertically downward.

Ricinus communis also grows straight roots in water. Of the

twenty-three seedlings used none curved in the water stream. Ten roots were in revolving water for 20 hours, and thirteen other roots for 48 hours, in temperature from 19° to 24°, in velocities from 150^{cm} to 1200^{cm} per minute, without one curve of any kind appearing.

Quercus alba was hardly sufficiently tested. Only six seedlings were tried, and no root of these was rheotropic. The duration of the experiment was 48 hours, the roots elongating 1^{cm} to 2^{cm} in that period. The velocity of the current was 225^{cm} to 600^{cm} per minute.

Cucurbita pepo and *Citrullus vulgaris* grow primary roots very straight in an environment of water. Of the former species, forty-four seedlings have been used in five different experiments, in which the water temperature ranged from 17° to 23°, the velocity of current from 150^{cm} to 2000^{cm} per minute, and the duration of the experiments from 13.5 hours to 9 days. In none of these was any deviation from the vertical shown.

In *Citrullus vulgaris* thirty-one seedlings were employed in three experiments, the water temperature in two being 21° and in the third 24°. The revolution of water lasted in two for 17 hours, and for the third 24 hours. The velocity of current was from 100^{cm} to 1300^{cm} per minute. Only three slight positive curves were formed. In such a very slight result it may be assumed that the bending was not a response to the current, and hence *Citrullus vulgaris* may be accounted non-rheotropic.

Phaseolus vulgaris, *P. lunatus*, *P. multiflorus*, *Glycine hispida*, and *Dolichos lablab* have all shown themselves non-responsive to the flowing of water. The three species of Phaseolus and Dolichos produce many crooked roots in water; Glycine mostly straight roots. In all these experiments the contorted roots have been excluded from the results, and only those showing themselves straight after standing for 10 to 24 hours in still water were used subsequently in the flowing water. The smallest number of seedlings employed in any species was ten, and the largest forty-seven, with a total of 137. The water temperature in some cases was held constant throughout the

experiment, and in others varied from 17° to 25°. The period ranged from 8 to 36 hours. Dolichos showed a very few roots inclined positively, and it is possibly rheotropic in a very low degree.

3. *Plants with a low degree of sensitiveness.*

It has already been intimated that the roots of the bulb of *Allium cepa*, and the primary roots of *Dolichos lablab*, may be slightly positively rheotropic. It is quite certain that the primary roots of the seedlings of *Vicia faba*, *Lathyrus odoratus*, *Lupinus albus*, and *Tropaeolum majus* are positively rheotropic, but only in a comparatively low degree. Juel, in several tests with seedlings of the small-seeded variety of *Vicia faba*, had trouble in controlling the Sachs's curvature. He obtained varying responses and a considerable number of non-responsive roots. He finally concluded that the roots were rheotropic, and bent more readily when so placed that the median plane of the seedling was parallel with the current rather than transverse.

My own experiments were not troubled with Sachs's curvature because of my method of securing the seedlings, and my results agree in a general way with those of Juel, though my plants were mostly of the variety known as "Windsor broad." Apparently, however, this variety is less responsive than that used by Juel, since, as will be seen, the Windsor broad shows many individuals as neutral, while it would be inferred from Juel's narrative that very few of his roots were neutral. Thus, among thirty-seven selected seedlings in four experiments with revolving basins of water, water temperature 19° to 23°, velocity of current 100^{cm} to 2500^{cm}, seventeen grew positively, three negatively, and seventeen were neutral. In two experiments, in each of which nine seedlings were suspended with their roots dipping into a brook of water in a wooded ravine in August, the average temperature being about 23°, all eighteen roots remained vertical, though increasing in length from 1^{cm} to 2^{cm} in the period. In the one experiment the period was 24 hours, and the velocity 450^{cm} per minute; in the other, the period was fourteen hours, and the velocity 900^{cm} per minute.

In a variety of *Vicia faba* with seeds 1.5^{cm} long and 1^{cm} broad, perhaps the same used by Juel, twelve seedlings were placed under experiment with the revolving basin, water temperature 21°, velocity 300^{cm} to 750^{cm} per minute, and period 24 hours. Six roots then showed positive curves from 15° to 90°, and the other six were vertical.

As to the relative degree of response shown by the seedlings when the median plane is parallel to the current of water and when the median plane is transverse, my results, and probably those of Juel, are too few to account as of great importance. In one experiment with six seedlings, with the median plane transverse to the current, four roots out of six responded positively, the greatest angle being 30°. In another experiment with ten seedlings, the median plane being parallel to the current, eight roots bent positively, two of them reaching an angle of 80°. In a third experiment with twelve roots, out of nine with the median plane parallel, four bent positively, while out of three with the median plane transverse, two bent positively. Thus it is shown that the root will respond to the water meeting it on any part of its circumference.

The low grade of responsiveness of *Vicia faba* to a current of water is shown not only in the fact of approximately 50 per cent. of the roots remaining neutral, but also in the exceedingly protracted latent period, and in the small angle attained in most curves. Thus in the experiment with the twelve seedlings of the small-seeded *Vicia faba* with a water temperature of 21°, no roots curved in the first 5 hours. In 8 hours four had curved positively, in 16 hours five had curved, and within the following 8 hours one more curved. Of the twenty-three positively curved roots in both varieties of *Vicia faba*, only three attained angles greater than 45° degrees from the vertical. The majority of curves were below 30°.

Lathyrus odoratus and *Lupinus albus* are, at least in some varieties, positively rheotropic. The latter was found rheotropic by Berg. Both these species produce fairly straight roots when growing in water. With water temperature from 21° to 24°

during a period of 24 hours, only three roots curved out of fifteen seedlings of mixed varieties of *Lathyrus odoratus*. In another group of twenty seedlings, in water temperature of 20° to 22°, only three or four weak curves showed after 24 hours, but fourteen good positive curves showed after 48 hours. Of the others, two were negative and four remained vertical. In a small-seeded variety of *Lupinus albus*, at a water temperature of 27°, sixteen seedlings in the revolving basins of water gave no curved roots during the period of 29 hours. A later experiment with a large-seeded variety, temperature in the water being 17° to 23° and the period 25 hours, gave twenty-two positively curved primary roots in a total of twenty-four. Each of the curves attained an angle of 45° or over. The velocities employed in the experiments with both these species extended from 50^{cm} to 500^{cm} per minute.

It is evident, therefore, that both these species have sensitive primary roots. Whether the varying sensitiveness observed was due entirely to the different varieties, or, in part, to temperature, to different seasons of the year, or to some other condition, was not determined. Enough testing was done to show that it was not due to difference in the water used in the experiments.

Tropaeolum majus behaves badly in water, 25 per cent. to 50 per cent. of the roots becoming contorted. In two experiments, with a total of thirteen straight roots, the period of revolution for one being 12 hours, and for the other 18 hours, the temperature of the water being 22° to 23°, and the velocities ranging from 225^{cm} to 625^{cm} per minute, no roots responded. In another experiment, same temperature, velocities from 100^{cm} to 900^{cm} per minute, twenty seedlings were used. No curve appeared for 6 hours; but at the end of 30 hours, fifteen of the primary roots were positive 15° to 19°, while the other five were pointing vertically downward. The secondary roots gave no certain response. There was considerable irregularity in the direction of growth, but, at the end of the period, the fifteen primary roots showed plainly that this species gives a rheotropic reaction.

4. *Plants with a high degree of sensitiveness.*

It has already been stated (p. 183) that in 134 individuals of four large-fruited varieties of Indian corn so many primary roots grew contorted in water that these plants are wholly unsuited for experiment. At the same time it is to be remembered that Jönsson, Berg, and Juel have found *Zea mays* rheotropic, though none of them states the variety used.

If instead of the large-fruited varieties of *Zea mays* we experiment with the dwarf *Zea mays*, with the white popcorn, we shall soon find this variety in its primary root highly sensitive to a current of water. Quite unlike the contorted roots of the field and sweet corn, the primary roots of the popcorn nearly all grow straight in water. In a total of seventy-nine seedlings in velocities of water of 25^{cm} to 1000^{cm} per minute, period 36 hours, and water temperature 19° to 23°, fifty-seven primary roots showed positive curves, six negative curves, and sixteen roots were neutral. A few of the negative curves were doubtless caused by the mechanical effect of the strongest current employed. The percentage of positive roots is here made but seventy-two, about the same as that of *Vicia sativa*. But many of the angles attained by the roots of the popcorn approximate 90° from the vertical, as shown in *fig. 3*. The general behavior of this seedling is so much better than that of *Vicia sativa*, that we are justified in according it a higher degree of responsiveness.

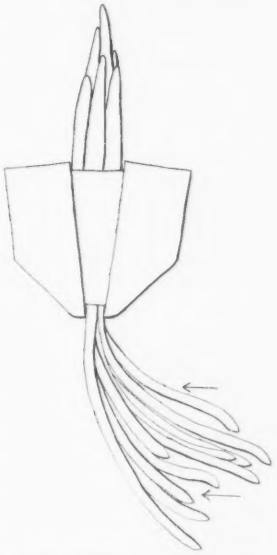

FIG. 3.—*Zea mays* (popcorn). End view of a row of ten seedlings after being in the water stream for 11 hours. The general direction of the roots is more than 45° from the vertical, and the tips of several are nearly 90° from the vertical. The drawing shows the actual size of the preparation, the seedlings growing from a wooden trough and being held in position by packing of cotton wool.

The Gramineae other than Zea, so far as studied, are also positively rheotropic. *Triticum vulgare* and *Secale cereale* were so determined by Jönsson, *Hordeum vulgare* and *Avena sativa* by Berg. In my experiments all four of these species were treated as already described for other plants. After the grains had been placed in the vertical position in sawdust, and there sprouted, they were secured in the vertical position, by means of strips of blotting paper and rubber bands, to the sides of wooden bars extending parallel with the diameter of cylindrical glass basins, and so placed that the lower ends of the grains just met the contained water. Here the preparation rested till the roots had attained a length of one or more centimeters. The revolution was then started. At once the question arises as to how these roots should be judged; for, as is well known, the roots of the cereals grow out in a bunch of several to many secondary members which do not all take the vertical direction till a considerable length is reached. The method finally found the most satisfactory was as follows: When a record was to be made the observer sighted horizontally along the row of roots, counting all roots positive whose apical portion deviated from a vertical plane in the direction against the stream, all roots negative that deviated from the vertical in the direction with the stream, and all roots neutral whose tips were in a vertical plane parallel with the row of seedlings. In placing the grains in position on the supports care was taken to arrange them so that about an equal number met the water current on the flanks, on the front, and on the back. Thus it would seem that there could be no objection to the method employed for judging of the rheotropism of these plants. An error in calling a root positively rheotropic that was only inclined against the stream because of its plagiotropic position would be counterbalanced by calling a root a negative that was inclined in the opposite direction, solely through its plagiotropism, provided the number of individuals employed was large. The results will show such a preponderance in favor of rheotropic response that there can be no question of the fact.

In *Triticum vulgare* ninety-three roots were observed, divided among three experiments. Temperature of the water was from 19° to 22°, velocity from 75^{cm} to 750^{cm} per minute (constant for any one root), period 24 hours for two experiments, and 48 hours for the third. Twenty-five roots were positive, three were negative, and sixty-five were neutral. The angles attained were not more than 20° from the vertical. This would seem to place the wheat among those of weak response to a current of water.

Secale cereale furnished sixty-two roots for observation, temperature of water 20° to 23°, velocity 100^{cm} to 1000^{cm} per minute, period of 15 hours. Fifty-nine roots were positive and three neutral. Several of the angles attained were 90°.

Hordeum vulgare had 102 roots under experiment in a water temperature of 20° to 22°, a velocity of 50^{cm} to 750^{cm} per minute, and periods of 7, 9, and 24 hours. Of positive roots there were eighty-four, negative seven, and neutral eleven.

Avena sativa was tested in five experiments with a total of 132 roots. The water temperature was 21° to 25°, the velocity of current 50^{cm} to 1000^{cm} per minute, and the period 9 hours to 33 hours. Ninety-seven roots bent positively, six negatively, and twenty-nine remained neutral. Many of the roots bent to an angle of 60°.

The four species of Gramineae just considered resemble one another in the production of good roots in water, in displaying positive rheotropism, and in producing a considerable percentage of neutral roots. The wheat shows the smallest number of responses of these four plants.

Of the Leguminosae, ten species have been studied, five being found non-responsive, and five responsive. All but the two most sensitive species have already received attention.

Vicia sativa was pronounced by Juel very sensitive to a stream of water. This author had not tried the much more sensitive Cruciferae. In my experiments *Vicia sativa* has proved itself relatively slow and weak in its response. It responds better than *Vicia faba*, but much less readily than a dozen other plants whose behavior is to be described later.

The experiments with *Vicia sativa* may be divided into two groups: those of a duration of 6 hours to 12 hours, and those of 48 hours. Forty-seven seedlings have had their roots stimulated by currents of water ranging in velocity from 150^{cm} to 750^{cm} per minute, water temperature 19° to 25°, period from 6 to 12 hours, giving twenty positive and twenty-seven neutral roots. Had the revolution of the basins of water been continued longer, it is certain that other roots would have become positive, as is shown by the following results: Eight seedlings had their roots subjected to the streaming of water in a revolving basin for 48 hours, water temperature 18° to 21°, velocity 450^{cm} to 500^{cm} per minute, giving seven roots positive and one negative. In another experiment, out of thirteen seedlings only two showed curves after 12 hours' revolution of the basin, while after another 12 hours ten roots had become positive. It is safe to assume that over 75 per cent. of the roots of *Vicia sativa* are responsive to the flowing of water, whereas only 50 per cent. of those of *Vicia faba* are responsive.

Both of these species are alike in the long duration of the latent period and in the smallness of the angle of curvature. It is certain that in my experiments with these two species, in a water temperature of 20° and an air temperature of 21.5° or higher, more than half the roots to respond rheotropically have shown the first curving later than 8 hours. Not 15 per cent. of those responding have shown a curve earlier than 6 hours. The greatest angle that any of my seedlings of Vicia has attained is 70°; the most of them have reached a deviation of 10° to 25°. *Fig. 4* shows a tracing from a photographic reproduction of the seedlings in one of the foreging experiments, and, with the restriction contained in the description accompanying the figure, is fairly representative of the behavior of this plant.

Pisum sativum resembles in its general behavior *Vicia sativa*. A number of its roots grow crooked in water, its latent period is long, and a considerable number of its roots are non-responsive. It shows, however, a higher percentage of curvatures in response to the stimulus, and the angle attained by the roots is greater

than in *Vicia sativa*. In this series the temperature was kept constant throughout at 23° in air, almost the optimum for the growth of this species and variety; the velocity ranged from 50^{cm} to 1380^{cm} per minute and the period from 16 to 22 hours. Of the ninety-four roots used, seventy-four bent positively, ten negatively, and ten grew vertically. Of the seventy-four positive roots, sixty-one attained an angle between 45° and 90°; several reached 90°.

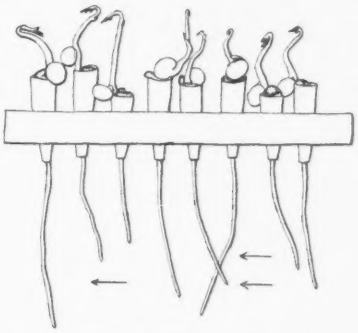

FIG. 4.—Tracing from a photograph, half natural size, of *Vicia sativa*. The seedlings were packed in glass tubes with cotton wool, and the tubes held in holes in a wooden bar. In order to secure a photograph to show the curves to best advantage, the bar was suspended parallel to the water-stream. It was found, however, that the resulting curves were not so great as when the row of seedlings extended, as usual, transversely to the stream. The smaller angles attained were probably due to the interference of the roots with the stream. This figure is presented principally for the purpose of comparing the sensitiveness of this species with that of *Raphanus sativus*, as shown in *figs. 6* and *7*, page 198. As is not unusual in this species, the figure shows one root with a negative curve.

Among the Polygonaceae only *Fagopyrum esculentum* has been put under experiment. The primary roots of the buckwheat are evidently highly sensitive, but they show some inclination to form sudden curves in still water. Even though the roots grow irregularly in water, the contorted roots will bend their tips against a stream a short time after it is started. Twenty-six straight roots were selected for experiment. The temperature during the three experiments was respectively 21°, 18°, and 22° in the air. The velocity ranged from 75^{cm} to 750^{cm} per minute, and the periods were 24, 18, and 12 hours. Twenty-four roots became positive, and two negative. My notes record the angles of only seventeen of these twenty-six roots: thirteen bent positively to an angle of 90°, one to an angle of 15°, and two bent

negatively to an angle of 90°. The last two, and perhaps some others, evidently curved, not because of the stream, but because of their objection to the water environment, whatever this objection may be. The relatively large number of positive roots, however, warrants us in concluding that this species is rheotropic.

Of the Compositae only *Helianthus annuus* has been used. Forty seedlings have been tested for a period long enough to determine their rheotropism. The temperature was 21° to 23° in air, the velocity 50^{cm} to 1000^{cm} per minute, the period 17 to 33 hours. Twenty-eight roots bent positively, six negatively, and seven were neutral. The roots bending positively did not attain as great an angle as those of Fagopyrum, less than one-half passing beyond 45°. The roots of Helianthus do not all grow straight in still water, and this behavior will account for the relatively large number of negative curves in the experiments.

The Cruciferae have furnished by far the best material for the study of rheotropism. Of the six species studied, five are rheotropic, only *Nasturtium officinale* showing itself wholly indifferent. The white mustard, the black mustard, the turnip, the cabbage, and the radish, but especially the first and the last of these five, give splendid examples of rheotropic roots. All of the Cruciferae tried produce straight roots in water. In size, the seedlings used were from 2^{cm} to 4^{cm} in length at the beginning of the experiment.

Brassica alba is one of the best of the eighteen species that have been found rheotropic. In five experiments with the revolving basins of water, in which fifty-one seedlings were used, with a velocity of 50^{cm} to 1000^{cm} per minute, a water temperature of 19° to 22°, and a period from 6 to 21 hours, forty-five roots bent strongly positively, the majority being over 45°, and many being 90°. Six roots were neutral. This gives a percentage of 88 and marks the white mustard as a remarkably good plant for experiment. Its great heliotropic sensitiveness requires that the experiments for rheotropism be carried on in the dark. *Fig. 5* shows the curves obtained in one experiment with this plant.

Brassica nigra responds more slowly than *Brassica alba* but attains almost as good a percentage, and almost as great angles. The sensitiveness of its roots to light requires that it, too, be kept in the dark in determining its rheotropism. Twenty-nine seedlings were used in two experiments with the revolving basins, the water temperature being 24°, the velocity 50^{cm} to 450^{cm} per minute, and the periods 9 hours and 15 hours. Twenty-four roots became positive and five remained neutral. In the experiment with the longer period, all of the roots that became positive, numbering fifteen, were 45° to 90° from the vertical. The result gives us 83 per cent of responsive roots.

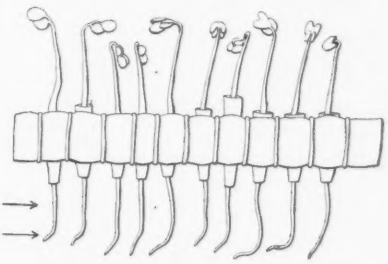

FIG. 5.—*Brassica alba.* A tracing from a photograph, three-fourths natural size. These seedlings were set in glass tubes in order to facilitate transfer for purposes of photographing. During the experiment the bar was held in a radius of the revolving basin for 18 hours, water temperature 21°, the range of velocities being 125^{cm} to 600^{cm} per minute. At the conclusion, the seedlings were twisted around through an arc of 90° in order to show their angles in the photograph. The figure is fairly representative, except that the tips declined slightly during the preparation for photographing.

Brassica campestris was tested in two experiments with a total of forty-two seedlings, water temperature 24°, velocity of current 60^{cm} to 560^{cm} per minute, period 24 hours, giving thirty-six positive curves averaging 45°, three negative curves, and three neutral roots. This gives a percentage of eighty-five positive roots. It will be noted that that the angle attained in these experiments is rather small. It may have been due to the rather high temperature. *Fig. 2* shows the result obtained in one experiment with this plant.

Brassica oleracea was tested in two experiments, water temperature 24°, velocity 60^{cm} to 560^{cm} per minute, and period 20 hours. Thirty-four seedlings were used, of which thirty-two curved positively to an angle of 15° to 80°, while two curved

negatively to an angle of 20°, giving a percentage of ninety-four positive roots.

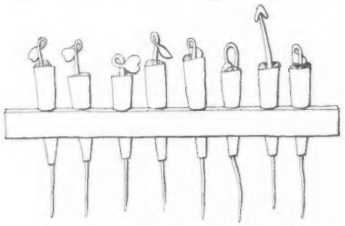

FIG. 6.—*Raphanus sativus* before the beginning of the experiment which gave the result in *fig.* 7. Tracing from photograph.

Raphanus sativus, the variety known as the "early long scarlet," has been for me the best of all plants for experiments with rheotropism. It is larger than any of the other Cruciferae worked with, and for that reason less liable to injury in handling. Its roots are insensitive to light, and hence experiments with it may be conducted in the general rooms of the laboratory. In the series described here, 140 seedlings have been used in nine experiments with the revolving basins of water. The water temperature has ranged from 20° to 25°, the velocity from 50^{cm} to 750^{cm} per minute, and the period from 5 to 33 hours. One hundred and twenty-three roots have bent positively, the majority from 45° to 90°; eight have bent negatively, and nine have grown vertically. The positive roots are, therefore, 87 per cent. The response of this plant to the water stream is relatively very ready. Two hours from the beginning, at a suitable temperature, well marked curves can be detected in 25 per cent. to 50 per cent. of the roots. The relative response of this plant and of *Vicia sativa* is well shown by comparing *figs.* 4 and 7.

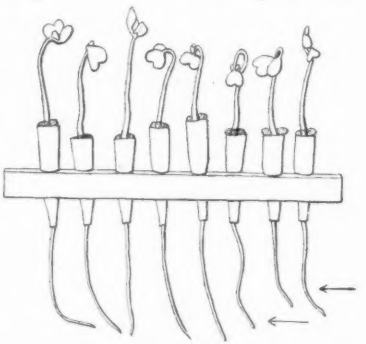

FIG. 7.—*Raphanus sativus*, tracing from a photograph. This figure is to be compared with *fig.* 4. The two give fairly well the relative response of *Vicia sativa* and *Raphanus sativus* in similar conditions. The experiments for both were carried on at the same time, the period of revolution being 23 hours, the temperature in water 19° to 22°, and the range of velocities 100^{cm} to 500^{cm} per minute. As stated under *fig.* 4, these preparations were made for photographing, and the curves are smaller than they would have been had not the bar of seedlings been held parallel with the stream of water.

[*To be continued.*]

A DESCRIPTIVE LIST OF THE PLANTS COLLECTED BY DR. F. E. BLAISDELL AT NOME CITY, ALASKA.

ALICE EASTWOOD.

[*Continued from p. 149*]

SAXIFRAGACEAE.

83. CHRYSOSPLENIUM TETRANDRUM Fries. Bot. Not. 193.—Leaves reniform, crenately 5-lobed: flowers green, inconspicuous: in fruit the carpels separate, showing the tiny red seeds, each of which is fastened to the walls of the capsule by a slender, very short funiculus. The entire plant is perfectly smooth and less than 1^{dm} high.

Comparison made from description by Dr. J. N. Rose, in BOT. GAZ. 23: 275.

84. PARNASSIA KOTZEBUEI Cham. & Schlecht. Linnaea 1: 549. 1826.—Scapes 6–15^{cm} high, slender, usually with a cauline leaf near the base: leaves clustered at base, ovate to orbicular, on petioles once or twice the length of the blade (that on the stem leaf very short): sepals oblong, a little shorter than the petals: petals white, 3–5-nerved, elliptical: stamens with filaments varying in length, shorter than the petals; anthers orbicular, notched at each end, more deeply so at base; staminodia yellow, 3–5 united, inserted at the base of each petal: capsule surpassing the persistent floral organs; stigma sessile, of four spherical lobes.

Type locality: "in insula Unalaschka ad Sinus bonae spei, Escholtzii et St. Laurentii."

85. PARNASSIA PALUSTRIS L. Sp. Pl. 273. 1753.—Scape slender, 6–20^{cm} high, with one cauline leaf below the middle, sessile and cordate clasping: radical leaves on slender petioles, orbicular-ovate, obtuse, usually cordate at base: sepals linear-oblong, callous-tipped, half shorter than the petals: petals sessile, broadly elliptical, white, 5-veined, obtuse or emarginate at apex: staminodia 16, united and unguiculate; stamens with filaments varying

in length, shorter than the petals, linear-attenuate; anthers elliptical: capsule purplish, with the stigmatic lobes recurved.

Type range: "in Europae uliginosis."

86. SAXIFRAGA ADSCENDENS L. Sp. Pl. 405. 1753.—A low, small-flowered species, with the small rosulate radical leaves pedately 3-cleft: flowers panicled, the peduncles stipitate-glandular below, glandular-puberulent above: petals slightly surpassing the obtuse sepals, white, and with noticeable parallel venation.

Type range: "in Pyrenaeis Baldo, Tauro Rastadiensi."

87. SAXIFRAGA BRONCHIALIS L. Sp. Pl. 400. 1753.—Matted at base with low slender stems rising from a rosulate tuft of leaves; these linear, acute, with conspicuous white-ciliate margins; stem leaves linear, appressed: flowers yellowish-white, dotted with yellow, smooth except for a few scattered short gland-tipped hairs: petals oblong, unguiculate,

This is quite unlike the plant of the Rocky mountain region which has been included under this species.

Type range: "in Sibiria."

88. SAXIFRAGA COMOSA Britton Mem. Torr. Bot. Club **5**: 178. 1894. *Saxifraga stellaris comosa* Poir in Lam. Encycl. **6**: 680. 1804.—Scape slender, sparingly glandular-villous, about 8–12^{cm} high, naked up to the little bunches of leaves which take the place of flowers: flowers when present terminating the scape: calyx with minute, roundish, purple divisions: petals with oblong blades, white with two yellow spots at base, truncate or cordate at base, oblong, acute, 3^{mm} long; claw one-third as long as the blade: stamens with flat linear-acuminate filaments, shorter than the petals; anthers suborbicular, dark purple: leaves in a cluster at base, broadly oblanceolate, toothed at apex, sparingly ciliate with bristly hairs.

89. SAXIFRAGA FLAGELLARIS Willd. ex Sternb. Rev. Saxifrag. 25, *pl. 6.* 1812; Hook. Fl. Bor.-Am. **1**: 253. *pl. 87.*—A well-marked species, sending out long filiform runners which root at the ends: dead leaves densely imbricated on the caudex, obovate-spatulate, conspicuously ciliate; upper leaves and stem

glandular: corolla bright yellow, with obovate petals about 1^{cm} long.

90. SAXIFRAGA HIERACIFOLIA Waldst. & Kit. Pl. Rar. Hung. 1 : 17. *pl. 18.* 1802–1812; Hook. Fl. Bor.-Am. 1 : 249.—This belongs to the group which includes *S. nivalis* L., and is distinguished by black-purple flowers which are interruptedly spicate-glomerate. The pollen is bright orange. The scape is clothed with viscid-arachnoid jointed hairs, and sometimes has one leaf. Radical leaves elliptical-oblong, with margined petioles and crenate margins.

91. SAXIFRAGA HIRCULIS L. Sp. Pl. 402. 1753.—Stems matted at base, clothed with oblanceolate, dead, brown leaves: leaves few on the stem, clothed with jointed arachnoid brownish hairs: flowers few on each stem: petals yellow, linear-oblong, obtuse, about 1^{cm} long, the lower half generally orange-dotted.

This is a beautiful and showy species.

Type range: "in Suecia, Helvetia, Lapponia, Sibiria."

92. SAXIFRAGA OPPOSITIFOLIA L. Sp. Pl. 402. 1753.—Stems prostrate, creeping: leaves imbricated in fours, fleshy, ciliate, with a pore in the center of each near the apex: stem one-flowered, 12^{mm} high, one-leaved: capsule surpassing the divisions of the calyx: stamens shorter than the petals, which in the specimens examined were withered.

Type range: "in rupibus Alpium Spitzbergensium, Lapponicarum, Pyrenaicarum, Helveticarum."

93. SAXIFRAGA PUNCTATA L. Sp. Pl. 401. 1753.—Leaves all radical, reniform, crenate-dentate: flowers small, white, at first capitate-corymbose, later in fruit becoming panicled: white petals ovate with cuneate base, retuse apex, and punctate with tiny numerous close dots: pubescence viscid-arachnoid with the hairs on the upper part of the stem gland-tipped: follicles tinged with purple, divaricate, tipped with sessile stigmas: the specimens are variable in size, from 5^{cm} to 1–2^{dm}.

Type range: "in Sibiria."

94. SAXIFRAGA RIVULARIS L. Sp. Pl. 404. 1753.—A small-flowered species with many low stems from fibrous roots: leaves

3–5-lobed, very small, cuneate at base, the pubescence arachnoid with woolly viscid hairs: flowers few, terminating the slender branches: calyx often with purple-tipped divisions: petals white, tinged with purple, oblong, veiny: stigmas sessile, divaricate.

Type range: "ad Alpium Lapponicarum latera et rivulos."

95. SAXIFRAGA RICHARDSONIANA Hook. Fl. Bor.-Am. 1:247. 1840.—About 3^{dm} high, with orbicular-reniform leaves $2.5–5^{cm}$ broad: petioles, scapes, and lower surface of leaves clothed with scattered black glands, leaf margins doubly dentate: flowers large, in racemes that become spiciform: acuminate sepals purplish, with few gland-tipped hairs: petals white, unguiculate, obovate-elliptical, abruptly acuminate, twice as long as the sepals.

This is beautifully figured in *Botany Beechey* under the name of *S. Nelsoniana* H. & A., p. 124. *pl. 29.*

ROSACEAE.

96. COMARUM PALUSTRE L. Sp. Pl. 502. 1753.—Stems erect, with few compound leaves, each consisting of 5 oblong-obovate leaflets with deeply serrate-dentate margins, green on the upper surface, pale beneath: all parts of the flowers red-purple, the petals much shorter than the sepals.

Type range: "in Europa uliginosis."

97. DRYAS OCTOPETALA L. Sp. Pl. 501. 1753.—This beautiful plant is widely spread through both parts of the northern hemisphere, forming mats: leaves oblong, pinnately lobed with oblong lobes, hairy, margins revolute, veiny and glossy on the upper surface, white tomentose on the lower: corolla white, 2.5^{cm} in diameter: calyx with narrowly linear divisions clothed with black hairs: fruiting akenes tipped with feathery styles resembling those of Pulsatilla.

Type range: "in Alpibus Lapponicis, Helveticis, Austriacis, Sabandicis, Hibernicis, Sibiricis."

97*a*. DRYAS INTEGRIFOLIA Vahl. in Scriv. Naturh. Selsk. Kjoeb. 4: 11. 1798.—Similar to the preceding, but with leaves narrower, the margins entire and revolute.

98. GEUM ROSSII Seringe, DC. Prodr. **11**: 553. 1825. *Sieversia Rossii* R. Brown, Parry's First Voy. App. 276. 1824.—Stems clothed at base with the brown sheathing petioles and stipules of dead leaves, glabrous below, 3^{cm}–3^{dm} high, 1 or 2-flowered, with some bract-like leaves scattered along the flowering stem: leaves interruptedly pinnate, the larger divisions irregularly lobed at the top, the smaller ones much smaller, entire: calyx open-campanulate, often brownish-red, pubescent: corolla yellow, 2^{cm} in diameter, with the petals suborbicular, obcordate, veiny: stamens numerous on filiform filaments inserted on the calyx: pistils with very slender straight styles and akenes hispid with upwardly spreading hairs.

Superficially this resembles some species of Potentilla.

99. POTENTILLA BIFLORA Willd. ex Schlecht. in Gen. Naturf. Fr. Berol. Mag. **7**: 297. 1813.—Caudex clothed with brown broad sheathing stipules: leaves with linear, revolute divisions, hairy on the margins and lower surface, and with a tuft of hairs at the apex: scapes 1–2-flowered: calyx appendages linear, narrower than the ovate divisions, almost equaling them in length: petals obcordate, with the base a deeper yellow than the upper part: akenes glabrous, reddish at summit and tipped with long reddish styles, at base beset with long hairs which give the receptacle a woolly appearance.

100. POTENTILLA FRUTICOSA L. Sp. Pl. 495. 1753.—A widely distributed species, and easily distinguished from the other species by its shrubby habit. The akenes are woolly, and the corolla yellow, 2^{cm} in diameter.

Type range: "in Eboraco, Anglia, Oelandia, Australi, Sibiria." This has been segregated from Potentilla by P. A. Rydberg as Rafinesque's *Dasiphora* (Mem. Dept. Bot. Columb. Univ. **7**: 188).

101. POTENTILLA UNIFLORA Ledeb. Mem. Acad. Petersb. **5**: 543. 1812.—Cespitose, the caudex clothed with brown dry stipules: leaves cinereous on the upper surface, densely white-tomentose on the lower: leaflets 3, palmately wedge-shaped, 3–5-cleft: flowers 1 or rarely **2** on the stem: calyx white-hairy, with bractlets almost as broad and long as the ovate-lanceolate

divisions: corolla with obcordate petals, glabrous, veiny, keeled on the back with a sharp margined ridge: styles shorter than the akenes.

King mountain.

102. RUBUS ARCTICUS GRANDIFLORUS Ledeb. Fl. Ross. **2**: 70.— Stems low: leaves trifoliate, with the leaflets cuneate and entire at base, dentate from below the middle to the apex: flowers rose-color, 2–3^{cm} in diameter.

Type locality: "in America arctica ad sin. Kotzebue."

103. RUBUS CHAMAEMORUS L. Sp. 494. 1753.— Low, with leaves simple, orbicular-reniform in outline, 3–5-lobed, and margins irregularly dentate: flowers white, 2^{cm} in diameter.

Type range: "in Sueciae paludibus uliginosis, turfosis frequens."

104. SANGUISORBA MEDIA L. Sp. Pl. ed. 2. 169.— Stems erect, 3–4^{dm} high: leaves mostly radical, compound with 9–11 petiolulate leaflets, the lowest pair smallest, oblong-ovate; the largest 3^{cm} long, and almost 2^{cm} wide, coarsely dentate, glabrous, paler on the lower surface, often tinged with purple; cauline leaves 3 or 2, with fewer and narrower leaflets; stipules dentate: flowers in a dense spike 1–2^{cm} long, purple.

Type locality: "in Canada."

105. SPIRAEA BETULAEFLORA Pall. Fl. Ross. *pl. 16.* 1784–1788.— Low shrub, with slender erect branches clothed with reddish-brown bark: leaves on short petioles, broadly oval, crenate-serrate except near the base, glabrous, paler on the lower surface: corymbs sessile: flowers small, white, 6^{mm} in diameter: stamens much exserted: sepals reflexed, deltoid: follicles pubescent on the line of dehiscence, tipped by styles of almost equal length.

Type range: "in Sibiria orientali ad fl. maja."

LEGUMINOSAE.

106. ASTRAGALUS ALPINUS L. Sp. Pl. 760. 1753.— This pretty little Astragalus is readily recognized by the capitate flower-cluster on a long peduncle, with the flowers and pods pendent:

the calyx and pods are clothed with black hairs: the corolla is white tinged with rose-color: leaflets small, canescent.

Type range: "in Alpibus, Lapponicis, Helveticis."

107. **Hedysarum auriculatum,** n. sp.—Stems 2–3^{cm} high, generally with two or three flowering erect branches, striate, appressed downy-pubescent: leaflets 9–13, petiolulate, lanceolate, aristate, 1–2.7^{cm} long, about 5^{mm} wide, veins prominent, lower surface with scattered pubescence, upper glabrous; petioles very short or wanting; stipules brown, sheathing, membranous, 2-cleft to below the middle with divisions attenuate: racemes 5–13^{cm} long, on long peduncles, with flowers pendent on recurved pedicels; bracts deciduous, linear-attenuate; bractlets narrowly linear, close under the calyx: calyx with one large subulate tooth opposite a broad sinus, the other four equal and shorter, about half as long as the tube, hairy pubescent on both surfaces: corolla rose-color, 12^{mm} long; keel 1^{cm} long, auricled at base, obtuse at apex; claws 4^{mm} long; wings linear, three times as long as the claws, less than 2^{mm} wide; banner obovate, emarginate, 1^{cm} long, 5^{mm} wide: pods consisting of 2–4 orbicular to oblong joints, glabrous, margined, veiny, 5–10^{mm} long.

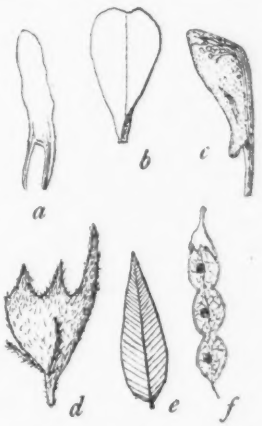

FIG. 4.—*Hedysarum auriculatum: a*, wing, × 2; *b*, standard, × 2; *c*, keel, × 2; *d*, calyx, × 5; *e*, leaf, nat. size; *f*, pod, nat. size.

Along the banks of streams.

108. **Hedysarum truncatum,** n. sp.—Stems erect, 2–2.5^{dm} high, slender, striate, subcinereous with scattered white hairs: leaflets 9–11, short-petiolulate, oval to ovate-lanceolate, mucronate, 10–15^{mm} long, veins prominent, pubescent a little on the midrib and margins; stipules brown, membranous, sheathing, with two attenuate apices: racemes 1 or 2, generally on peduncles about 6^{cm} long: flowers pendent, rose-color, 17^{mm} long:

calyx with two divisions subulate, one-third as long as the tube, densely hairy on both sides, thickened on the midrib: corolla glabrous; keel 1^{cm} long, twice as long as the claw, truncate at base, obtuse at apex; wings linear-oblong, eight times as long as the claws; standard cuneate, obcordate at apex, 15^{mm} long: pods with 1–3 joints, which are glabrous, reticulate, orbicular-oval, becoming 6^{mm} or more long, and margined all around.

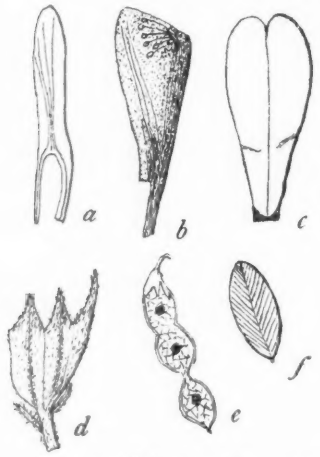

FIG. 5.—*Hedysarum truncatum*: *a*, wing, × 2; *b*, keel, × 2; *c*, standard, × 2; *d*, calyx. × 5; *e*, pod, nat. size; *f*, leaf, nat. size.

This is near *H. alpinum* Willd. as delineated in Bot. Reg. *pl. 808*. It differs in pubescence, shape of leaflets, truncate keel, and fewer joints to the pod. Scattered over the tundra.

109. OXYTROPIS LEUCANTHA Pers. Syn. 2: 331. *Astragalus leucanthus* Pall. Astragal. 59. 1800. — The specimens collected were in flower only: flowers yellow, in short oblong heads terminating the one or two scapes: caudex densely clothed with dead brown stipules and petioles: leaves and scapes cinereous with appressed hairs mixed with occasional longer ones; the pubescence of the leaves chiefly on the margins and midrib: calyx densely clothed with long black hairs mixed with a few white ones.

According to the description in Gray's revision in *Proc. Am. Acad.* 20: 1–7, the flowers of the specimens seen by Dr. Gray were "well suffused with violet." These are distinctly yellow, without a tinge of violet. It may be some other species, or perhaps new.

Type locality: "in Sibiria."

110. OXYTROPIS MERTENSIANA Turcz. Bull. Soc. Mosc. 68. 1840; Ledeb. Fl. Ross. 1: 584.—Leaves 3–5 or solitary: flowers purple, in 2–3-flowered heads: calyx clothed with black or brownish hairs which are also on the erect pods: pod shortly

stipitate, the ventral suture intruded so as to almost divide the pod into two cells.

Type locality: "in terra Tschutschorum ad sinum St. Laurentii."

EMPETRACEAE.

111. EMPETRUM NIGRUM L. Sp. Pl. 1022. 1753.— A heather-like prostrate shrub, forming dense beds a few centimeters high, with small crowded linear thick-keeled glossy leaves about 2–4^{mm} long: young stems and leaf margins glandular: midrib sunken on one side, invisible on the other: flowers inconspicuous and solitary in the upper axils: sepals and petals 3, purplish: stamens 3, exserted: pistillate flowers with a globose ovary surmounted by a short thick style having 6–9-toothed segments: fruit a blue-black berry known as "crow berry" and "heath berry."

The minute glands on the younger stems and margins of the leaves seem not to have been noted in any description seen by me, though these glands are to be found on all the most northern plants in the Herbarium of the California Academy of Sciences.

Type range; "in Europae frigidissimae montosis paludosis."

VIOLACEAE.

112. VIOLA BIFLORA L. Sp. Pl. 936. (1753).—Stems slender, ascending: leaves round-reniform, obtuse or acute, 1–2^{cm} wide, somewhat pubescent; lower ones on long petioles; upper ones on petioles but little longer than the blades; margins crenulate-denticulate, ciliate; stipules green, ovate-acuminate: flowers 1 or 2, yellow marked with brown lines on the largest petal, which is 1^{cm} long: sepals linear-subulate, 3–4^{mm} long; spur blunt, short: capsules pubescent: seeds mottled with brown, with a prominent rhaphe at the pointed end.

Type range: "in Alpibus Lapponiae, Austriae, Helvetiae, Angliae.

113. VIOLA PALUSTRIS L. Sp. Pl. 934. 1753.— Rootstock slender, creeping: leaves round-reniform, all basal, obscurely crenulate, glabrous; petioles generally shorter than the 2-bracted, 1-flowered scape: sepals ovate, white margined: corolla white, about 1^{cm} long, the lowest petal veined with purple, all without

beard in the throat; spur short, rounded, of about equal length and breadth.

Only two specimens were collected, both in flower, and not good.
Type range: "in Europae frigidioris paludibus."

ONAGRACEAE.

114. EPILOBIUM LATIFOLIUM L. Sp. Pl. 347. 1753.—Stems less than 2^{dm} high, generally ascending, leafy to the base, minutely puberulent throughout, and somewhat canescent on the younger parts: leaves sessile, opposite or alternate, ovate-elliptical or lanceolate, with scattered callous teeth on the margin; midrib evident, but other veins obscure: flowers axillary or in racemes with leaf-like bracts on pedicels as long as the ovary: buds at first erect, then pendent, and again erect before anthesis: sepals crimson, linear-acuminate, shorter than the petals, 2^{mm} wide: petals a lighter shade of crimson, rhombic-ovate, somewhat unequal, about 2^{cm} long, and almost 1^{cm} wide, tapering at both ends: capsules erect spreading, 6^{cm} long, purplish, tapering at each end with the apex truncate: coma tawny.

Type range: "in Sibiria."

115. EPILOBIUM SPICATUM Lam. Fl. Fr. 3:482. 1778.—Entire plant glabrous: stems about 5^{dm} high, with the lower leaves scale-like: upper leaves opposite or verticillate in threes, lanceolate-acuminate, revolute with a few gland-like teeth along the upper margin, about 6^{cm} long, sessile at base, veiny: flowers in racemes, reflexed in bud, with the lower bracts leaf-like; upper ones minute; pedicels spreading, a little shorter than the ovary: calyx lobes crimson, oblanceolate, mucronate: petals obovate, 7^{mm} long, surpassing the calyx lobes, crimson: stamens 8, with filiform filaments shorter than the petals: style as long as the filaments; stigma with 4 divergent lobes: capsule becoming twice as long as the pedicels, 3^{cm}, purple, narrowed at each end, but with the apex truncate: coma on seeds dingy white.

UMBELLIFERAE.

116. HERACLEUM LANATUM Michx. Fl. 1: 166. 1803.—This is easily distinguished from all other members of this family by

the large ternate leaves with broad round-cordate cut-toothed leaflets: umbels large, and petals of the outer flowers generally dilated and 2-cleft.

The leaf-stalks and stems of this plant are used as food by the aborigines. Along the streams and near springs.

Type range: "in Canada."

CORNACEAE.

117. CORNUS SUECICA L. Sp. Pl. 118. 1753.—Distinguished from its near relative, *C. canadensis* L., by the 2-forked stem at the leaf axils of the first flowers.

Under the willows.

Type range: "in Suecia, Norvegica, Russia."

ERICACEAE.

118. ARCTOSTAPHYLOS ALPINA Spreng. Syst. **2**: 287. *Arbutus alpina* L. Sp. Pl. 395. 1753.—Stems forming mats with woody branches, creeping: leaves thin, deciduous, obovate-elliptical, acute, tapering at base to a margined petiole, ciliate when young, about half as long as the blade; margin serrate; surface smooth, veiny, turning reddish-purple: fruit a red, juicy berry, containing 5 seeds.

The berries which were collected and preserved in formalin may not be ripe. According to the descriptions they are black when ripe.

Type range: "in Alpibus Lapponiae, Helvetiae, Sibiriae."

119. ANDROMEDA POLIFOLIA L. Sp. Pl. 393, 1753; Fl. Lapp. *pl. 1. fig. 3.*—This pretty little plant has globular urn-shaped, rose-colored flowers in few-flowered terminal umbels: the narrow leaves are so strongly revolute as often to show only the midrib, sometimes not even that; lower leaf surface pale, upper bright green.

Type locality: "in defertis subhumidis muscosis and paludosis etiam in Alpibus immer per totam Sueciam, mixta vaccinio crescit."

120. CASSIOPE TETRAGONA Don. Edinburg. N. Phil. Jour. **17**: 158. 1834. *Andromeda tetragona* L. Sp. Pl. 393. 1753.—Leaves imbricated in four ranks, each with a groove down the middle: the pretty white bells are at the summit of the stems and hang from the top of erect thread-like peduncles.

Type locality: "in Alpibus Lapponicis."

121. LEDUM PALUSTRIS L. Sp. Pl. 391. 1753.—Shrub with leaves linear, revolute, clothed with brown wool on the lower surface, marked with quadrangular veining on the upper: flowers white, in corymbs terminating the branches.

Type range: "in Europae septentrionalis paludibus uliginosis."

122. LOISLEURIA PROCUMBENS Desv. Journ. Bot. 1: 35. 1808. *Azalea procumbens* L. Sp. Pl. 151. 1753; Fl. Lapp. *pl. 6. fig. 2.*—A pretty little prostrate suffrutescent plant, with small crimson open-campanulate flowers in umbels terminating the stems.

Type range: "in Alpibus Europae."

123. RHODODENDRON KAMTCHATICUM Pall. Fl. Ross. 1: 48. *pl. 33.*—One of the most beautiful of arctic plants: leaves obovate-spatulate, veiny, bristly-ciliate: flowers rich crimson, with the calyx persistent and the divisions of the corolla almost an inch long.

Type locality: "Kamtchatka."

124. RHODODENDRON LAPPONICUM Wahl. Fl. Suec. 249. 1824. *Azalea Lapponica* L. Sp. Pl. 151. 1753.—A low much branched prostrate shrub about 8^{cm} high, with rough brownish bark, the outer part splitting irregularly into small plates: leaves clustered at the ends of the branches, oblong to elliptical or even ovate, $3–10^{mm}$ long, about half as wide, with entire revolute margins, mucronate apex, subcuneate base, midrib sulcate on the upper surface and prominent on the lower, surface minutely pitted, the pits covered with a brown scale, denser on the lower surface: flowers on peduncles a little longer than the petioles, 2 or 3 at the ends of the branches, apparently without bracts: calyx of 4 very short round divisions about 1^{mm} long and wide, green or purplish, ciliate, lepidote with greenish scales: corolla purple, rotate-campanulate, of 4 oblong-orbicular lobes twice as long as the tube, 3 larger than the fourth, wavy-margined, hairy in the throat, glabrous otherwise: stamens 7 or 8: style purple, twice geniculate; stigma capitate; ovary narrowly ovoid, lepidote.

There was but one specimen of this collected, and the peculiarity of the

four divisions of the perianth may be an individual characteristic. In other respects it resembles the figure in Bot. Mag. *pl. 3106*.

Type range: "in Alpibus Lapponiae."

125. VACCINIUM ULIGINOSUM L. Sp. Pl. 350. 1753.—This arctic huckleberry has solitary or clustered, pendent, globular urn-shaped flowers: leaves deciduous, pale and veiny on the lower surface, smooth or puberulent on both sides, with revolute margin, and obtuse, retuse, or sometimes mucronate apex: berry said to be blue-black, covered with a bloom when ripe.

Type range: "in Sueciae borealibus and alpinis; uliginosis."

DIAPENSIACEAE.

126. DIAPENSIA LAPPONICA L. Sp. Pl. 141. 1753; Fl. Lapp *pl. 1. fig. 1*.—Suggests a plant belonging to the Ericaceae, with its mat of shining evergreen leaves: stamens inserted in the sinus of the lobes of the corolla, and anthers obliquely dehiscent: capsule loculicidally 3-valved.

The pretty white flowers suggest those of *Moneses uniflora* Gray.

Type locality: "in Alpibus Lapponicis."

PRIMULACEAE.

127. ANDROSACE CHAMAEJASME Willd. Sp. Pl. 1: 799. 1797.—This pretty little primrose differs from the common form of this variable species. The corolla is white with a yellow eye, later turning purplish with the eye purple. The leaves are small and clustered at base in a rosulate bunch. The flowers are small in a capitate umbel, terminating a slender scape about 3^{cm} high.

Type locality: "in Austriae alpibus."

128. DODECATHEON FRIGIDUM Ch. and Schl. Linnaea 1: 223. 1826.—Scape from 5^{cm} to 3^{dm} high (in fruit): roots fleshy-fibrous, from an oblique rootstock: leaves spatulate, oval or almost orbicular to ovate, glabrous; margin sinuate: umbels 2–3-flowered, with diavaricate pedicels glandular-puberulent with purple glands (this pubescence also found on the calyx and the upper part of the scape): involucre of short, subulate bracts: flowers nodding, violet: divisions of calyx deltoid, 2^{mm} long:

lobes of corolla ligulate, 15^{mm} long: anthers on very short filaments, connate: capsule about twice as long as the calyx, the top falling off when the seeds are ripe.

Type locality: "frigidissima loca Sinus St. Laurentii, a nive defluente irrigata."

129. PRIMULA MISTASSINICA Michx. Fl. Am. Bor. 1: 124. 1803.—Roots fibrous, white: leaves clustered at the base of the scape, elliptical, dentate in the upper part, cuneate and entire in the lower; petioles from almost none to twice the length of the blade, sheathing at base: scape about 1^{dm} high, slender: umbel 2–many-flowered; involucre of narrow linear-acuminate bracts; pedicels varying in length from 2–10^{mm}: calyx of narrowly deltoid minutely puberulent divisions about equaling the tube of the corolla: corolla white with yellow tube, the limb consisting of five 2-lobed divisions.

Type locality: "ad lacus Mistassins Canadam inter et fretum Hudsonis."

130. PRIMULA NIVALIS Pall. It. 3: 320, 444; App. 723. *pl. G. fig. 2;* Ch. & Schl. Linnaea 1: 215.—Roots fleshy-fibrous: leaves and scape from a stout caudex clothed with broad ovate scarious scales: leaves broadly lanceolate, narrowed to the petiole, which is somewhat shorter than the blade; margins from entire to sinuate-dentate: scape slender, 2–3 times as long as the leaves: umbel few-flowered; involucre, upper part of scape, pedicels, and calyx more or less farinose; bracts of involucre linear-acuminate: divisions of the calyx longer than the tube, black-purple, edged with white-farinose margins, about half as long as the tube of the corolla: corolla crimson, salverform, with elliptical divisions shorter than the tube: flowers nodding at first, later becoming erect.

There are some fragmentary specimens with many-flowered umbels and shorter and stouter scapes and pedicels. This species appears to vary extremely. Chamisso and Schlechtendal describe the various forms which they found in different localities. Two flowering stalks which are very young, having the flowers declined on one side in a farinose umbel, are probably specimens of *Primula eximia* Greene, Pittonia 3: 251.

131. TRIENTALIS EUROPAEA ARCTICA Ledeb. Fl. Ross. 3: 25.

1846–1851. *T. arctica* Fisch. Hook. Fl. Bor.-Am. 2: 121. 1840. —Stems very slender, filiform, about 7 cm high, with 1 or 2 very small leaves (not more than 5 mm long) below the whorl: whorled leaves oblanceolate to obovate, entire, thin, varying in size from 5–15 mm: flower solitary on a filiform stem about as long as the rest of the plant: sepals 6, narrowly linear-acuminate, reddish: petals white, narrowly obovate or elliptical, mucronate at apex, 5 mm long, almost twice as long as the sepals.

In regard to *T. Europaea* in Fl. Lapp., Linnaeus says that the divisions of the corolla are acute when the plant grows in dry places, obtuse in wet places. This differs from *T. arctica*, according to the description, in having petals mucronate instead of obtuse.

Type range: "Western shore and islands, from Sandy bay, in Clarence straits (Tolmie), to Unalashka, Langsdorff, Chamisso."

PLUMBAGINACEAE.

132. ARMERIA VULGARIS Willd. Enum. 133. *Statice Armeria* L. Sp. Pl. 274. 1753.—Root vertical, slender, fusiform: caudex densely clothed below with the brown sheathing dilated petioles of former leaves; above with the rosulate cluster of green leaves: these linear, obtuse or acute, about as broad as the scape and 2–4 times shorter, ciliate on the margins, otherwise entire: scapes glabrous, 1–2 dm high, capped by the head of flowers; lowest bracts sheathing the stem, connate, laciniate, brown; outer ones brown tinged with pink, orbicular or broadly ovate, glabrous, scarious; inner ones among the flowers similar but thinner, equaling the flowers: these on short slender pedicels: calyx with the border 5-toothed, with erosely margined submuticous teeth, ribbed, hairy on the ribs below, white suffused with pink; tube turbinate, with 10 ribs densely clothed with upwardly-appressed hairs.

This is one of the numerous forms of this variable species, some of which have been described as distinct.

[*To be concluded.*]

AN EMBRYOLOGICAL STUDY OF LIMNOCHARIS EMARGINATA.

JOHN GALENTINE HALL.

(WITH PLATE IX)

Limnocharis emarginata is of South American origin. The plants from which material was taken for study are growing in a large tank in the aquatic house at North Easton, under conditions that appear to be normal, and are certainly favorable for propagation, as is shown by the maturing of abundant seed from the self-pollinated flowers, and the large number of seedlings that spring up spontaneously in the tank.

The discrepancies in the comparative embryology of the group to which Limnocharis belongs, as represented by the work of Marshall Ward, Schaffner, Campbell, and others, seemed to justify careful examination of the present material. I shall give no account of the general morphology, as Buchenau has described the development of the flower and of the tissue of the growing point.

The ovules in their general development follow very closely the development of the ovules of *Butomus umbellatus* as described by Marshall Ward. They arise as emergences from the walls of the carpels without definite placental arrangement. The subsequent development is of the usual angiospermous type, except the history of the embryo sac. Each integument is composed of two layers of cells, the inner being a trifle longer than the outer, and forming a considerable mass of tissue at the apex of the ovule around the micropyle, as is the case in Naias and Zannichellia. From the outer coat, soon after fertilization, certain cells begin to develop into short hairs that give the seed a rough appearance. Long before the seed coats begin to form, the growth of the ovule is more rapid on one side (*fig. 3*), and anatropy is already marked when the rudiments of the coats make their appearance (*fig. 4*).

Very early it is possible to distinguish the single hypodermal cell that forms the archesporium (*fig. 2*). It is somewhat larger than the surrounding cells, and the nucleus is considerably larger than those of the adjacent cells. There is a tapetum cut off by the archesporial cell, such as is described by Campbell for Naias and Zannichellia. In Limnocharis, however, the tapetal cell is without a wall, and it is pushed towards the apex of the sac (*fig. 4*), where it disappears in the later stages of development. The large cell left after the formation of the tapetum becomes the embryo sac without further division. About the time the first division takes place in the embryo sac the epidermal cell that overlies it divides by a periclinal wall, forming a false tapetal cell (*fig. 4*). In Butomus, according to Marshall Ward, there are two cells cut off in succession from the apex of the archesporial cells, and sometimes the first one divides once longitudinally. These three cells have very deliquescent walls, and soon disappear.

The history of the nuclear changes in the embryo sac differs considerably from the ordinary in the last stages. After the first division of the megaspore nucleus, the two daughter nuclei migrate to each end of the sac. The one that goes to the micropylar end passes through the usual divisions to form the egg apparatus and upper polar nucleus; while the one that goes to the antipodal end remains undivided (*figs. 5–8*). In Butomus, Marshall Ward says that sometimes only two nuclei are formed at the antipodal end of the sac, and that one of these fuses with the upper polar, leaving only one antipodal. The antipodal is not cut off by a wall from the sac in Limnocharis, Butomus, or Alisma, while in Sagittaria, Naias, and Zannichellia cell walls are formed around each of the antipodal nuclei.

The secondary nucleus at the micropylar end of the sac divides transversely (*fig. 5*), and then each of the resulting nuclei divides longitudinally (*figs. 6–7*), but not always simultaneously, making the usual four at that end of the sac. The lower one of the two nuclei, by division, makes the egg and upper polar; while the other forms the two synergids.

At this time, the upper polar nucleus (*fig. 8*) begins a migration toward the antipodal end of the sac, at the same time increasing somewhat in size, so that it has very much the appearance of an endosperm nucleus. This migration continues until the nucleus reaches the region of the antipodal nucleus (*fig. 9*), though no fusion takes place, for the latter can be seen in all but the very latest stages of the embryo sac and embryo. The upper polar nucleus, when it has approached the antipodal end of the sac, divides transversely (*fig. 10*). The lower daughter nucleus remains in the position of its formation, being cut off by a wall across the sac (*figs. 11–12*), and forming a large cell that does not divide further, but finally disappears through the encroachment of the endosperm. In *Butomus umbellatus*, Marshall Ward says that the two polars approach the middle of the sac, where they fuse, forming a definitive nucleus, and leaving only one antipodal nucleus. In Sagittaria, Schaffner shows a similar division of a large nucleus, and formation of a wall across the sac, near the antipodal end, which he says takes place after the fusion of the polar nuclei; and he states that frequently the nucleus of the cell cut off toward the lower end of the sac divides to form two or three, when the embryo is in about an eight-celled stage. Campbell describes a similar large nucleus in both Naias and Zannichellia, but does not state definitely what is its origin. He makes no mention of any wall cutting it off from the rest of the endosperm, but suggests that it may be the lower polar nucleus. Such cannot possibly be the origin of the one in Limnocharis, because there is no lower polar formed. Campbell also says that the nucleus resembles the suspensor nucleus in Naias and Zannichellia, which is the case in Limnocharis, except that the nucleus stains more readily than the suspensor nucleus.

The upper daughter nucleus travels back toward the egg apparatus (*figs. 11, 12*), and by its further division forms the endosperm. At an early stage the endosperm consists of only a single layer of granular protoplasm lining the sac, in which are embedded free nuclei, as in Naias and Zannichellia; but later, in Limnocharis, walls are formed, although they are not easily

distinguishable. Schaffner says that the endosperm is not abundant in Alisma; but as he does not follow the development of the embryo far, might it not be, as in the present case, that it finally completely fills the sac?

Before the polar nucleus, which forms the endosperm, has gone through the first division, fertilization has taken place; for at this time the egg nucleus has divided so that there are now two nuclei in the young embryo (*fig. 12*), and the remains of the pollen tube can be seen in many cases. Actual fusion of sperm nucleus and egg was not observed. It is evident that fertilization takes place very soon after pollination, from the fact that matèrial killed within eighteen hours after pollination showed the embryo in a two-celled stage, with the disintegrating remains of the pollen tube near by. Fertilization probably occurs in the first night after pollination.

For the study of the development of the embryo, most of the ovules, which are U-shaped, were taken from the ovary and embedded in watch glasses for sectioning.

The first division of the egg after fertilization is transverse, and divides the cell into suspensor and embryo-cell (*fig. 13*). The original suspensor cell increases very much in size (*figs. 14–16*), has an exceptionally large nucleus, and never divides save in case of polyembryony. In this case it divides and subdivides to form an embryogenic mass, from which grow out as buds several young embryos (*figs. 17 a, b, c*), somewhat as in *Erythronium americanum* and *Tulipa Gesneri*. Whether these all mature or not I cannot say, for polyembryony is not very frequent, and I was unable to find any older stages than those shown in *figs. 17 a, b, c*, although I observed a number of younger stages.

The suspensor in the older embryo is not wholly composed of the original suspensor cell, but appropriates some of the cells that come from the first terminal segment until it contains sometimes four and even five cells (*figs. 28, 29*). The second division is always transverse (*fig. 14*), while the third division takes place in three different directions, transversely, vertically, and

obliquely (*figs. 15, 18, 19*). In cases it is vertical or oblique, the growing point and the cotyledon both arise from terminal segments, agreeing with Zannichellia in this particular, but differing from Naias. After having examined a very large amount of material, I have come to the conclusion that there is no regular order of division in the active nuclei of the young embryo, at least after the first two walls are formed (*figs. 15–27*), and have thought that where descriptions do not agree it should perhaps be ascribed to the variation of development rather than to any incorrect statements or observations of the earlier writers. In *figs. 24* and *25* there are four transverse walls formed; in *fig. 25* there is no sign of division of the terminal cell; while in *fig. 24* the terminal cell is in process of division. In *fig. 16* there are three transverse walls, the terminal cell being divided vertically, while the cell next to the suspensor is in process of division.

In the further development it was impossible to follow the order of the divisions, and in the older stages of the embryo it seemed that the growing point was of lateral origin always (*figs. 22, 28, 29, 30*). The mature embryo is U-shaped (*fig. 31*), and the growing point is in the basal quarter of the embryo, apparently wholly surrounded by the epidermal layer.

This work was done at the Ames Botanical Laboratory, North Easton, Mass., under the direction of Oakes Ames.

NORTH CAMBRIDGE, MASS.

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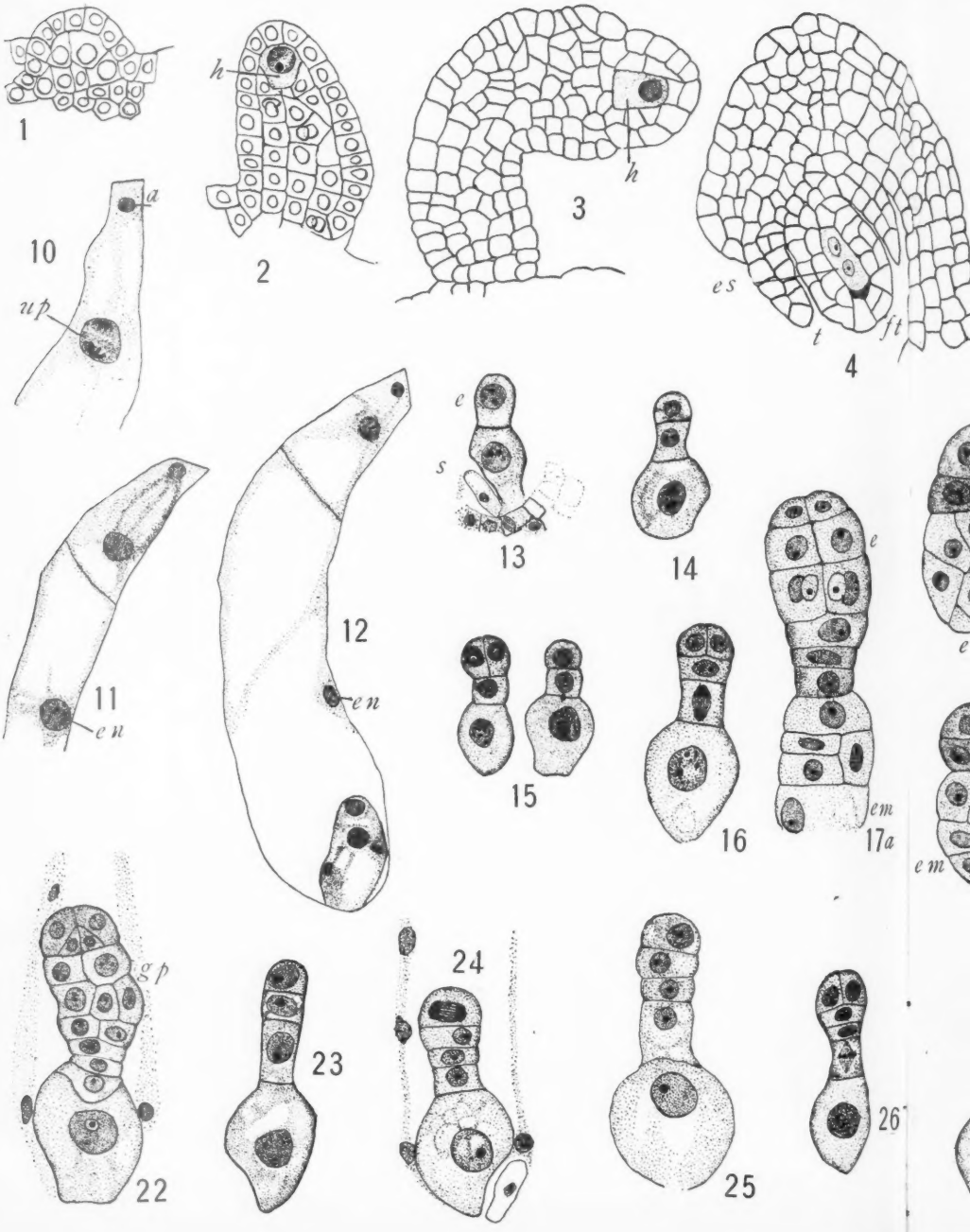
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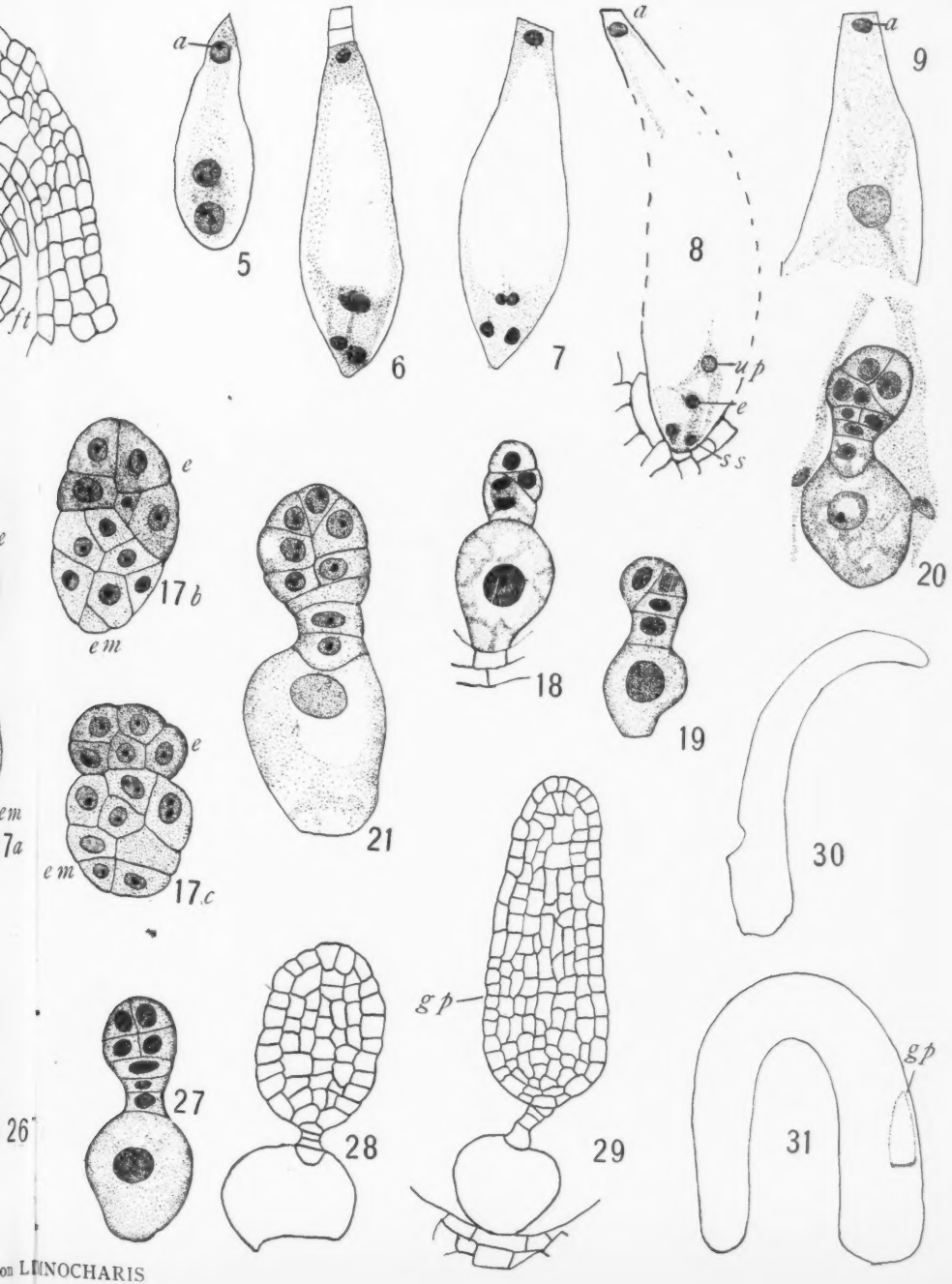
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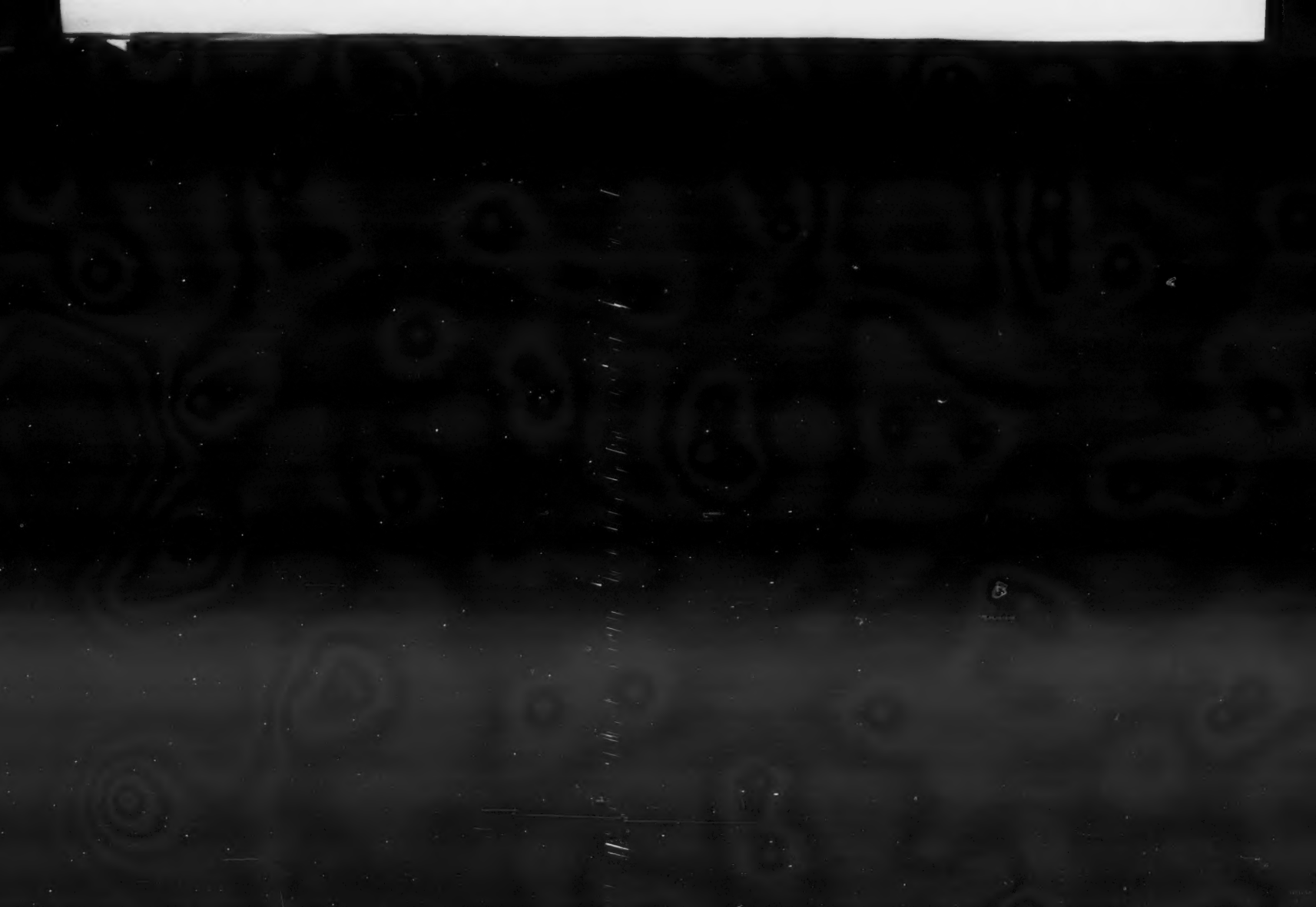

EXPLANATION OF PLATE IX.

FIG. 1 Very young ovule.

FIGS. 2, 3. Older stages of ovule showing archesporium (*h*).

FIG. 4. Ovule; *es*, embryo-sac; *ft*, false tapetal cell; *t*, tapetum.

FIGS. 5–7. Different stages of embryo-sac; *a*, antipodal.

FIG. 8. Mature embryo-sac; *a*, antipodal; *up*, upper polar; *e*, egg cell; *ss*, synergids.

FIGS. 9, 10. Lower end of embryo-sac showing antipodal (*a*) and upper polar (*up*) in process of division.

FIGS. 11, 12. Embryo-sac showing peculiar cell cut off from sac at antipodal end, and endosperm nucleus (*en*).

FIG. 13. Young embryo; *e*, "embryo-cell;" *s*, suspensor.

FIGS. 14–16. Succeeding stages of young embryo; *fig. 15*, two sections of same embryo.

FIGS. 17 *a*, *b*, *c*. Three sections of one embryogenic mass (*em*) with embryo-buds (*e*).

FIGS. 18–30. Stages of embryo; *gp*, growing point in *figs. 22–29*.

FIG. 31. Mature embryo; *gp*, growing point.

GENERIC NOMENCLATURE.

C. L. SHEAR.

THE application and limitation of generic names is a subject which has lately received considerable attention, not only from botanists, but from systematic biologists in general. Efforts to secure at least a degree of uniformity and stability in the use of scientific names have become more general in recent years, and quite naturally have been directed chiefly to specific designations. To one who will give the matter careful consideration, however, it must appear clear that the stability of the generic name is of primary importance, and must be secured before we can hope for stability of the binomial. I am aware that questions of nomenclature are considered beneath the notice of some botanists, especially some of those whose fields of labor do not bring them into very close contact with taxonomy; but there is no student of plant life in any of its multidudinous phases but must have occasion at some time to use plant names, and hence should be interested to some degree, at least, in any sincere effort to secure stability and uniformity in nomenclature.

Personally, I have long tried to avoid and evade the subject, believing that too great importance was attributed to it; and I am still far from regarding it as an equivalent for biological research; but having undertaken some taxonomic work, I found myself confronted by certain questions that must be decided.

The present discussion of this subject relates especially to the fungi, as I have made no special investigation of the conditions prevailing in any other group except the grasses.

To one who has never had occasion to trace the origin and history of a generic name through literature, it may appear that there is very little diversity in the application of such names, but a careful comparison of the use and interpretation of generic names by different authors soon reveals the fact that each

followed his favorite author or his individual preference or conception, which is not always based upon any serious consideration of the consequences, and leads naturally to little uniformity. An abundance of instances verifying this statement might be cited, but we shall take space to refer to only a few. Let us glance first at one or two of the older genera. Take for example the genus *Lycoperdon*. So far as we know, the name was first used by Tournefort,[1] who gave brief descriptions of twenty-eight species, including a considerable variety of Gasteromycetes. His plate illustrating the genus represents four species, two of which belong to the present genus as interpreted by DeToni.[2] The two others belong to distinct genera. It would require too much space to trace the entire history of the genus as interpreted by different authors down to the present time. Michelius[3] and most other authors until Linnæus used the name in much the same sense as Tournefort. Linnæus,[4] in *Genera Plantarum*, greatly enlarged the scope of the genus, and included many things previously separated by other authors. Interpreting his idea of the genus by the species referred to it in *Species Plantarum*, we have a very heterogeneous collection. Of the nine species described by him, but one is found in the genus as interpreted in Saccardo,[2] and even that one is not included by some recent authors. Myxomycetes, Ascomycetes, and Uredineæ are represented among Linnæus' species. Postlinnæan authors vary in their interpretation of the genus, and also as to whom it should be credited. The conceptions of Tournefort and Michelius, as shown in their illustrations of species, have apparently exercised the greatest influence, and have led to the present more or less general interpretation of the genus. The present application of the name is the natural outcome of following what might be called the lines of least resistance, which has lately been designated the "residue method," but was at first really no conscious method at all.

[1] TOURNEFORT, Ins. Rei Herb. 1:563. *pl. 331*. 1700.

[2] DETONI, Saccardo Syll. Fung. 7:106. 1888.

[3] MICHELIUS, Nov. Pl. Gen. 217. 1729. [4] LINNÆUS, Gen. Pl. 328. 1737.

The genus *Agaricus* affords another interesting example established by Tournefort,[5] who referred to it chiefly species of *Polyporus* in the sense of Saccardo, and figured as representing his idea of the genus, *Polyporus fomentarius* (L.) Fr. It was later taken up by Dillenius[6] and also Linnæus,[7] who referred to it chiefly lamellate forms. Since, the genus has been divided and subdivided until the name has become entirely displaced or relegated to a few imperfectly described species which could not be definitely referred. Karsten, Patouillard, and Saccardo[8] have applied the name to a group of species, including the common mushroom, *Agaricus campestris* L. But why should it be retained for this group rather than for any of the dozen or more groups to which it had equal claim? If any reason were given, it would probably be that this was the best known group, containing the species which has long been grown and collected for food.

The history of the genus *Sphaeria* Haller[9] is also very interesting, and shows how names are entirely displaced, or relegated to groups of insufficiently described species or indeterminate odds and ends of old authors.

Lest it should be inferred that such *laisser faire* proceedings are characteristic of the older authors only, we may call attention to one or two modern instances. Take the genus *Valsaria* Ces. & De Not.,[10] for example. Four species were positively referred to the genus and five others doubtfully by these authors. Later De Notaris[11] described and referred to the genus two

[5] TOURNEFORT, Ins. Rei Herb. 1: 562. *pl. 330.* 1700.

[6] DILLENIUS, Nov. Gen. 75. 1719.

[7] LINNÆUS, Gen. Pl. 327. 1737.—Sp. Pl. 2: 1171. 1753.

[8] SACCARDO, Syll. Fung. 5: 993. 1887.

[9] HALLER, Hist. Stirp. Helv. 3: 120. 1768.

[10] CESATI and DE NOTARIS, Schem. Sfer. Ital. Asc. in Comm. Crit. Soc. Ital. 1: 205. 1863.

[11] DE NOTARIS, G., Sfer. Ital. 57. 1863. This was published nearly a year after the last publication cited. The preface to fasc. 2, in which the above citation occurs, is dated December 1863, while the Schem. Sfer. Ital. is referred to in the preface to fasc. 1 which is dated March 1863, indicating that it appeared earlier in the year.

more species, the last of which was *V. tiliae*. Now note the treatment of this genus by two recent authors, Saccardo[12] and and Lindau.[13] Saccardo included most of the species originally referred to the genus by its authors and added a considerable number of others. Lindau cites De Notaris as the sole author of the genus, and restricts it to two species, only one of which is mentioned, *V. tiliae*, which was referred to the genus by De Notaris (*l. c.*), but was not included in it by the original authors, and was soon after taken as the type of the genus *Hercospora* by Tulasne.[14] It is scarcely worth while to multiply examples; any one who cares to look into the matter will find them without difficulty and in endless variety. For some cases of a similar sort among genera of ferns consult Underwood.[15]

It has been urged that instances of this kind are exceptional, but any one who takes the trouble to investigate the matter will find that they are exasperatingly frequent among the fungi, and I am told by those who have investigated the matter that the case is practically the same in other groups. The instances in which old generic names have been entirely displaced or transferred to different plants from those originally included are most numerous, and arise generally from the lack of uniformity in the subdivision or segregation of large or composite genera. A genus is divided into several subgenera, these are in turn raised to generic rank, the original name being entirely displaced or left with an undeterminable or miscellaneous residue, which the original author never included in it or at least did not regard as typical.

The first attempt, so far as we know, to formulate any rule for guidance in the segregation of large or composite genera was that of the Paris code, article 54 of which reads as follows:

> Lorsqu'un genre est divisé en deux ou plusieurs, le nom doit être conservé et il est donné à l'une des divisions principales. Si le genre contenait

[12] SACCARDO, Syll. Fung. 1: 741. 1882.

[13] LINDAU, Eng. and Prantl Pflanzenfamilien I. 1: 470. 1897.

[14] TULASNE, L. R. & C., Sel. Fung. Carp. 2: 154. S 1863.

[15] UNDERWOOD, L. M., Rev. Gen. Ferns, Mem. Torr. Bot. Club 6: 251 and 279. D 1899.

une section ou autre division qui, d'après son nom ou ses espèces, était le type ou l'origine du groupe, le nom est réservé pour cette partie. S'il n'existe pas de section ou subdivision pareille, mais qu'une des fractions détachées soit beaucoup plus nombreuse en espèces que les autres, c'est à elle que le nom doit être réservé.

This rule is so indefinite, and requires so much in the way of personal interpretation and judgment, that it has not produced uniform results in the hands of those who have sincerely attempted to use it as a guide. Kunze,[16] recognizing the impossibility of securing uniformity under this rule, proposed a modification of it which should make it more definite. As no particular period in the history of a genus is designated to be taken as a basis for applying the Paris code rule, Kunze very aptly remarks that it leaves us "über die höchst wichtige Frage im Unklaren." He emended this article so that it should require the generic name to be applied to the majority of the species included in the genus at the time of its valid establishment.

This has been designated the "species majority" method. While Kunze's amendment is a decided improvement, it is still incapable of giving us stability and uniformity in the application of generic names.

In the first place, it does not provide for the cases in which but two species were originally referred to a genus, either of which may be equally entitled to retain the name when the genus is divided. The fatal difficulty, however, is that the selection of the species which are to be considered as belonging to the genus must be based upon the reviser's conception of the genus, or upon the conception of the author that he may choose to follow, and it is quite unnecessary to call attention to the great diversity of generic concepts which has obtained, and still obtains, among botanists.

The Rochester rules make no direct provision for the treatment of genera, but refer all questions not particularly provided for to the Paris code.

The so-called "residue method" is the one which has been most generally accepted by adherents to the Rochester rules. I have

[16] KUNZE, O., Rev. Gen. Pl. 1: XCII. 1891.

long sought in vain for an authoritative statement of this method, but have until very recently been unable to learn of any attempt to formulate it. Thanks to Dr. Underwood,[17] who has bravely attacked the problem of generic types, we have the following statement: "The method of 'residues' works on the principle that the last species remaining in the genus from those originally named by its author when the genus was founded shall constitute the type of the genus and shall hold the generic name."

The fatal objection to this and to the other methods is that, being capable of and depending upon the varied interpretation by different authors, it cannot lead to uniformity. Besides this there are many instances in which several genera, each containing a number of species, were established at nearly the same time, which make it impossible to adjust generic limitations by means of this method.

The fundamental failing of all these plans is that the generic name remains movable, and is capable of being shifted about from one end of a series of species to the other, these species frequently representing different genera and sometimes families. As Dr. Jordan[18] aptly puts it: "These methods have lacked the one important element of inevitableness." The first and fundamental step to be taken is to fix generic names at one point by means of an assigned type, in case none was originally designated by the author. This method has already been proposed by Cook,[19] and also by Underwood, *l. c.* We can scarcely expect to secure entire uniformity in generic limitations, as various authors naturally differ in regard to the scope of genera, but if some practicable method can be devised for anchoring generic names at fixed points, we shall always know where to find at least the nucleus of the genus, however much it may have been enlarged or contracted since its origin.

The type method in regard to species has gained general recognition so far as present practice is concerned, though we regret to say that one still occasionally sees new species

[17] *Op. cit.*, 252. [18] JORDAN, D. S., Science N. S. **13**: 499. 29 Mr 1901.

[19] COOK, O. F., Science N. S. **8**: 186–190. 12 Ag 1898; 513–516. 14 O 1898.

described without the citation of a type specimen. The type method is equally or even more necessary and applicable in the case of genera; but admitting the advisability and possibility of such a method the details still remain to be arranged. Cook, *l. c.*, has discussed the question in general; Underwood, *l. c.*, has formulated a set of rules for fixing types and applied them to the genera of ferns; Jordan, *l. c.*, has also recently given us his views regarding the matter.

It seems very desirable and important that this matter should be thoroughly investigated and discussed before any fixed plan is adopted for putting the method into practice.

The essential features of any rule should be simplicity, clearness, and comprehensiveness. Rules which require or give opportunity for personal choice or interpretation cannot lead to uniform results. Provision should be made for all classes of cases involved, and this necessitates a thorough knowledge of all taxonomic literature. To one not familiar with the great diversity of practice among the botanists of the eighteenth century, the brief rule, "the first-named species of each genus shall be regarded as its type," would seem to fulfill all the requirements mentioned above. But would "the first-named species" apply to both polynomial and binomial species? And what would become of a genus whose author never referred to it a binomial species, but cited good figures of polynomial species? Rules will also have to be modified according to the time taken as a starting point for genera. The present starting point of the Rochester rules, 1753, seems very illogical and unsatisfactory for genera, and we believe will eventually be abandoned.

Let us examine briefly the various plans already proposed for the fixing of types. Mr. Cook, who was one of the first to propose the type method, has published no formal statement of rules, but says that genera should be fixed "by confining the application of a generic name to the genus in which its assigned type or first binomial species is included." Whatever the starting point might be this would require that genera established by polynomialists should be interpreted by their first successor using

their generic names with binomial species. Thus, in the case of Haller,[9] this plan would lead to the application of his generic names to different groups from those to which they would be applied by taking his first species as a type. It may be the intention, however, to disregard the genera of polynomialists entirely, as well as all those based upon descriptions not accompanied by direct citation of binomial species.

Dr. Underwood, *l. c.*, has formulated a series of rules and made a practical application of them. He adopts 1753 as his starting point, and designates what are to be regarded as valid genera as follows: "(*a*) based on one or more previously described species which are referred to with sufficient directness to be recognizable, or (*b*) based on some species which is described for the first time at the establishment of the genus itself."

For the selection of types the following rule is given: "For each genus established, the first named species will be regarded as the type." Two exceptions to this are made. One is that Linnæan genera must be traced to their types wherever they originated, and "in case the original generic name was used in another sense than that which it was adopted by Linnæus, the the type of the genus in the Linnæan sense must be determined wherever it was first used." The other exception covers cases in which "a definite statement of the type" is made by the author of the genus.

The application of these rules leads to entirely different results from those which would be reached by following Mr. Cook's plan. The difference is due in great part to the manner in which Dr. Underwood determines the types of Linnæan genera. Adopting 1753 as a starting point, and then selecting types for genera from Linnæus's earlier work, appears rather illogical. If types are to be taken from works earlier than 1753, why not date them accordingly? There also seems to be need of more definite provisions for determining the types of such genera as those of Adanson,[20] which are accepted by Underwood but do not appear to be interpreted according to any rigid rule.

[20] ADANSON, Fam. Pl. 1763.

We fear that other authors, attempting to follow these rules in an entirely unprejudiced manner, would not arrive at the same results. This, however, is distinctly an effort in the right direction, and due credit should be given for it.

Dr. Jordan, *l. c.*, in connection with his excellent review of the subject, suggests provisional rules for applying the type method. His rule 2, which covers the principal points at issue, is as follows: "If no type is designated by the author, either explicitly or by clear implication, then the first species referred to the genus or the species standing first on the page shall be considered as its type. A generic name should have no standing if resting on definition alone, nor until associated with some definite species."

With the exception of the expression "or by clear implication," this rule comes nearest to meeting the requirements for simplicity, clearness, and comprehensiveness. The phrase referred to, however, as well as several exceptions which the author adds, seems to present very undesirable opportunities for the exercise of personal opinion and choice, which are so fatal to uniformity.

It is not our intention to attempt to offer a set of rules which shall be perfect, and meet all the requirements of the case, but simply to avow our belief in the desirability and practicability of the type method, and to point out some of the matters which should be given careful consideration and investigation before any rules are generally adopted.

Of primary importance in this connection is the selection of a starting point for genera which may meet with general acceptance.

Definite provision should also be made for the treatment of genera having no binomial species referred to them at the time of their original description. It seems scarcely just to discard a generic name because it happened to originate with a polynomialist (*e. g.*, Haller, to cite a case after 1753), or in cases like that of Adanson, *l. c.*, when definite figures of identifiable species are cited instead of specific names.

It is to be hoped that careful consideration and study will be given to all the different phases of this subject, and that it will be thoroughly discussed from all points of view in order that any authoritative action in the way of formulating rules which may be taken may fully meet the requirements of the case and not prove premature.

WASHINGTON, D. C.

BRIEFER ARTICLES.

NOTES ON SOME AMERICAN TREES.

Fraxinus catawbiensis, n. sp.— A large tree 20–35^{m} in height, with a cylindrical or gently tapering trunk often 7^{dm} in diameter, and straight ascending branches forming an oval crown; the gray-brown bark on the trunk deeply furrowed, the ridges flat-topped and frequently anastomosing, that of the branches brown and smoother. Twigs stout, somewhat flattened and quadrangular between the nodes, about 5^{mm} thick, the first season dark brown and velvety with a close pubescence, becoming gray-brown and glabrate the second year, and marked with a few small pale gray lenticels; the winter-buds dark brown, scurfy, short and blunt; leaf-scars large, lunate or semi-orbicular. The leaves (2–3^{dm} long) borne on stout spreading velvety-pubescent petioles, consist of 7–9 drooping leaflets which are oblong-ovate, 7–10^{cm} long, 4–5^{cm} wide, rounded or subcordate at base, taper-pointed at the apex, usually entire, thick and firm in texture, dark green and glabrous on the upper surface, white and glaucous beneath, with brown pubescence on the midrib and primary veins; petiole short, velvety-pubescent. The flowers appear in the vicinity of Raleigh, N. C., from the first to the middle of April. The fruit, which is borne in loose pendent clusters, is about 3^{cm} long, the cylindrical brown body about 1^{cm} long and 3^{mm} thick, the narrow ligulate wing about 4^{mm} wide; ripens and falls in October; calyx glabrous, scarcely 1^{mm} long, sharply toothed.

The Catawba ash frequents the alluvial river banks of the Piedmont region of the Carolinas, growing with the black birch, red maple, sweet gum, the white and green ashes, and the bitternut hickory; and is not uncommon in the vicinity of Raleigh, N. C., at an altitude of 110^{m}, and Marion, N. C., along the Catawba river and its tributaries, at an altitude of 400^{m}. It is closely related to the white ash, from which it is separated by the darker foliage, glaucous white beneath, the soft pubescence of the twigs and petiole, and the darker winter-buds; while from *Fraxinus biltmoreana* and *F. profunda*, which it closely resembles in foliage and pubescence, it is separated by the shorter and smaller fruit and smaller calyx.

TILIA HETEROPHYLLA Vent.—The northern limit of this species is usually given in the mountains of Pennsylvania; this being the limit

assigned by Professor Sargent in his *Sylva*, and in the sixth edition of Gray's *Manual*, and in Britton and Brown's *Flora of the Northern States*. In 1892 the writer collected specimens of a linden from Fall creek, near Ithaca, N. Y., and in 1897 similar specimens from near Watkins glen, New York, which are undoubtedly from the white linden, having its close silvery pubescence on the lower surface of the leaves, and the subglobose fruit covered with short cinereous tomentum, characters common to no other species of the eastern United States.

Tilia eburnea, n. sp.—A tree 10–22^{m} in height, with dark gray-brown furrowed bark on the trunk, and smoother silver-gray bark on the branches. Twigs stout, 5–6^{mm} thick, soft, glabrous, occasionally sparingly glaucous, those of the season bright green, brown or red-brown, becoming gray the second year; buds large, ovate, glabrous, sometimes glaucous. The leaves are ovate or round-ovate, 8–14^{cm} long, 7–12^{cm} wide, abruptly acuminate at the apex, obliquely cordate or truncate at the entire base, sharply serrate, thick, dark green and glabrous above, densely pubescent beneath with soft white hairs which are sometimes deciduous by autumn; petioles and primary veins glabrous, often glaucous. The pedunculate bract is 10–12^{cm} long, oblong or spathulate, rounded at the apex, rounded or acute at base, sessile or nearly so, glabrate above, often soft-pubescent beneath. The flowers, which appear about the middle of June, are smaller than those of *Tilia heterophylla*, and the sepals and peduncles more pubescent than in that species. The ovary and young fruit are densely pubescent with short brown hairs; the mature fruit is 5–7^{mm} thick, globular or somewhat thicker than long, and not pointed.

From *Tilia heterophylla*, which it much resembles and with which it is often associated, *Tilia eburnea* is separated by the softer and looser pubescence on its foliage, its smaller flowers, somewhat earlier time of flowering, and the coarse brown tomentum of the ovary and fruit which is in strong contrast to the very close cinereous pubescence that clothes the fruit of *T. heterophylla*. From *T. pubescens* it is distinguished by having larger flowers, glabrous twigs, larger and broader foliage which is white (not gray or brown) pubescent beneath.

Tilia eburnea is found from middle North Carolina to northern Georgia between 200^{m} and 700^{m} elevation, on rich moist soil near small streams or on steep cool slopes. It is usually associated with the red oak, red maple, white ash, and yellow poplar, but is nowhere a common tree. In the cool hollows of the Blue ridge in North and South Carolina it occurs with the white linden and another related species which seems to be undescribed.

Crataegus cibilis, n. sp.—A tree 4–6^{m} in height, with a short unarmed trunk having dark gray nearly black scaly bark, and numerous long spreading branches forming a globose crown. Twigs soon glabrous, thick, soft, russet or red-brown, straight or nearly so, armed with very few short thorns 2–3^{cm} long. Leaves thin, on the upper surface bright green and glabrous except on the midrib, on the lower somewhat paler and sparingly pubescent, especially on the veins; the blades ovate deltoid or nearly orbicular, 7–9^{cm} long, 5–8^{cm} wide, rounded or truncate at the usually entire base, subacute or obtuse at the apex, sharply doubly serrate and with 2–4 pairs of short notches above the middle; petiole slender, one-half the length of the blade, villous. Inflorescence a nearly simple 4–8-flowered cyme; pedicels slender, erect, villous, the lower elongated. The flowers, which appear at Hot springs, North Carolina, early in May or the last of April, when the leaves are about half grown, are 20–24^{cm} wide; calyx large, cup-shaped, glabrous, the elongated ligulate or narrowly triangular sharply serrate lobes spreading or ascending after anthesis; stamens 20, anthers nearly white. The fruit, borne in nearly simple clusters, on long spreading or drooping nearly glabrous pedicels, and falling with the pedicels attached before or with the leaves in October, is depressed globose, 12–15^{mm} thick and not quite so long, concave at the base, full and rounded at the apex, dark red, capped by the large ascending calyx lobes; the cavity broad and deep; flesh thick, firm, yellow, sweet; seeds usually 5.7–8^{cm} long, lateral faces nearly plane, grooved on the narrow back.

The species above proposed is related to *Crataegus altrix*, proposed below, from which it is separated by the differently shaped foliage, and larger glabrous ascending calyx lobes. It occurs on the banks of the French Broad river in Madison county, North Carolina, and Indian creek, Unicoi county, Tennessee.

Crataegus altrix, n. sp.—Arborescent, 5–7^{m} in height, with a short usually unarmed trunk 1–2^{dm} thick, dividing above into numerous horizontal or spreading sparingly armed branches which form a globose or flattened crown; the bark on the trunk dark brown and broken by shallow furrows into narrow ridges, that on the branches light gray and smoother. Twigs brown, stout, glabrous, or nearly so, soft and brittle, somewhat geniculate, armed with few short (2–3^{cm}) thorns. Leaves ample, dark green and nearly glabrous above, more or less soft-pubescent on the lower surface, the blades ovate or broadly ovate,

7–13^{cm} long, 5–11^{cm} wide, rounded or truncate at the serrate base, acute or obtuse at the apex, sharply and coarsely serrate or doubly serrate, with a pair of prominent notches at the base, and often less conspicuous notches above, 6–8 pairs of prominent veins, the lowest pair spreading; petiole terete or nearly so, at first pubescent, at length nearly glabrous. Inflorescence a several-flowered somewhat compound cyme; pedicels strict, erect, at first pubescent, soon glabrate; calyx large, cup-shaped, soon glabrate, the oblong glabrate serrate or nearly entire lobes reflexed after anthesis and often deciduous before the fruit falls; flowers about 20^{mm} wide; stamens 20; anthers white; styles 4–5. The fruit, which falls in September or October before the leaves, borne in simple, few-fruited clusters on nodding or declined pedicels, is glabrous, globose, 13–18^{mm} thick, bright glossy red, sparingly glaucous, and often capped by the persistent reflexed lobes; flesh thick, deep yellow, very sweet; seeds 4–5, nearly central in the fruit, 6–7^{mm} long, somewhat grooved on the narrow back, the lateral faces plane.

The type material was collected by the writer along streams and in pastures in northern Illinois. *Crataegus altrix* is evidently related to *C. canadensis* Sarg., but has much larger foliage and fruit. It is more closely related perhaps to *C. cibilis*, above proposed, of the southern Appalachians.

Crataegus obtecta, n. sp.—A tree 3–5^{m} in height, with a short usually unarmed trunk covered with dark gray or nearly black rough or scaly bark, and with long spreading branches which form a round or flat-topped crown. Twigs at first villous with matted gray hairs, at length glabrate, thick, soft, russet-brown, straight or nearly so, armed with few short thorns. Leaves thin for the group even when mature, above dull green and at first pubescent, but soon glabrate, beneath soft pubescent; the blades ovate in outline, 7–12^{cm} long, 6–9^{cm} wide, rounded or broadly cuneate at the entire base, acuminate at the apex, sharply and coarsely doubly serrate, seldom notched; petiole slender, villous. Inflorescence a nearly simple 5–10-flowered villous cyme; the flowers, which appear in northern Illinois from the 1st to the 10th of May (early for the group) when the leaves are about half grown, are about 2^{cm} wide; calyx large, obconic, villous, the elongated triangular lobes pubescent, sharply glandular, serrate, spreading after anthesis; stamens 20, anthers white. The fruit, borne in usually simple clusters on long spreading villous or nearly glabrous pedicels, is pyriform 12–15^{mm} thick, dark red, glabrate except at the apex, capped by the

large ascending nearly sessile calyx-lobes; cavity broad and deep; flesh thick, yellow, very sweet; seeds usually 5, 6–8^{mm} long, grooved on the back, the lateral faces nearly plane.

The species above proposed is related to *C. mollis*, from which it is separated by the different outline of the leaf, with its very sharp serratures, more simple inflorescence, somewhat later period of flowering, and larger erect calyx-lobes. The fruit matures early in October and falls early.—W. W. ASHE, *Raleigh, N. C.*

BLACK ROT OF ORANGES.

A FUNGOUS disease of navel oranges has attracted attention in the orange-growing districts of California for the past eight or ten years, and was named black rot by the writer on account of the color of the diseased tissues. The losses due to this disease will run from 3 to 10 per cent. of the navel crop, and as the cultivation of the navel variety in the state is extensive the total losses are proportionately heavy.

Oranges are attacked through the navel, the fungus hyphae entering cracks or other imperfections of the peel of those parts. The cells of the pulp sacks are destroyed, and soon become black in color and bitter to the taste. The peel is left uninjured until the disease has made considerable progress within, but finally becomes thin and darkened in color over the affected parts. The fungus vegetates freely among the pulp sacks, which are wholly destroyed as far as the mycelium extends, but this destruction of tissue rarely involves more than one-fourth of the fruit, and is commonly confined to the tissues lying near to and at one side of the navel. Infected fruit ripens prematurely, showing an exceptionally high color, and soon falls from the tree.

The fungus inducing this disease is a new species of Alternaria, and its conidia are produced upon the surface of the affected tissues. The life cycle has been studied by means of single spore cultures, and detailed descriptions and illustrations are reserved for publication, together with facts relative to preventive treatment. The following specific characterization may be accredited to Ellis and Pierce.

Alternaria citri, n. sp.—In oranges in California. Effused, olivaceous, becoming nearly black. Mycelium abundant, loosely interwoven, gray, consisting of slender, septate, yellowish or olivaceous-hyaline threads, penetrating and overrunning the matrix, much

branched, the branches mostly a little swollen at the apex and bearing the terminal variously shaped conidia, which are obovate, oblong-elliptical or subglobose at first, 10–22 × 8–15 μ diam., and mostly 3-septate, finally large, 25–40 × 15–25 μ, short-clavate-oblong, 4–6-septate and slightly constricted at the septa, the cells divided by one or more longitudinal septa, dark olive-brown. The conidia are oftener 3–6-catenulate in series, either simple or branched. As shown by cultures, secondary conidia often arise directly from the primary, thus giving rise to a secondary series. The cells of the conidia at maturity incline to assume a spherical shape, and the conidia then resemble somewhat asci filled with globose sporidia.

From its habitat (inside the orange) and the character of the conidia this seems distinct from *A. tenuis* Nees, on orange leaves.—NEWTON B. PIERCE, *U. S. Dept. Agric., Bureau of Plant Industry, Pacific Coast Laboratory, Santa Ana, California.*

CURRENT LITERATURE.

BOOK REVIEWS.

The mutation theory.[1]

CONTRIBUTIONS TO the theory of evolution have been many, but in these later years progress has been very slow, largely because philosophical speculations and acrid discussions have dominated facts. The chief value of this great work of De Vries is that it makes a constant appeal to experiment and careful observation. The volume before us is but half of his work, doubtless the more important half, since it contains the brilliant experimental work which has led the author to present to the world his theory of the origin of species. The second volume is to deal with the principles of hybridization.

The theory of mutation is not new. Darwin recognized it especially in his earlier works, holding that "single variations" or sports have to be reckoned with, as well as natural selection. Through the influence of Wallace and others, natural selection has in most quarters come to be the ruling theory, though the importance of other factors has frequently been emphasized. As long ago as 1864 Kölliker appealed to heterogenesis, which is identical with mutation; the term "mutation" has been used by Scott and various writers, and the term "saltatory evolution" has been used by still others. Mutation involves the sudden origin of a new species without transitions or connecting links. Not all natural selectionists would find fault with this, since Darwin fully recognized the fact that selection improves rather than creates. Some selectionists, however, have held that natural selection is in reality a creative force, and to such De Vries has little comfort to give. Indeed, he discards natural selection altogether, so far as the evolution of species is concerned. Numerous experiments by the author and others show that there is a definite limit to individual variability, and that the full advantage of selection along any one line can usually be obtained within a very few generations, as in the parsnip or carrot. Again he claims that selection never fixes a character, but that reversion occurs after any number of generations of culture; apparent exceptions to these principles are due to hybridization or mutation. Thus natural selection can never create anything new; it can improve only within definite and narrow limits, and this improvement is possible only in artificial conditions. Mutation, on

[1] DE VRIES, HUGO: Die Mutationstheorie. Versuche und Beobachtungen über die Entstehung von Arten im Pflanzenreich, Vol. I. 8vo, pp. 648, with eight colored plates and many text figures. Leipzig: Veit & Co., 1901. See also Rev. Gén. Bot. 13: 5–17. 1901.

the other hand, brings into existence something altogether new, the mutant remains fixed from the outset, and if it is fit, it will survive the struggle for existence as a new species. Mutability and variability are sharply contrasted; variability is obviously governed by external factors, especially nutrition, while mutability has no such obvious connection. Thus we may say that most species are fixed and immutable, yet more or less variable from their origin to their final extinction.

De Vries accepts Jordan's idea of species, viz., that within the Linnean species there may be "elementary species" (varieties, of authors), which are experimentally immutable. Jordan found about 200 immutable forms within the ordinary species limits of *Draba verna;* hence the idea that *Draba verna* is a collective group, and that the 200 immutable forms represent true species. In such cases the author favors a trinomial nomenclature.

Of a number of natural species studied, *Oenothera Lamarckiana* was the only one which appeared to be in a state of mutability. This species was found naturalized on a field near Hilversum, Holland, about 1875, and has increased its area rapidly. When first observed by De Vries in 1886, two elementary species were noticed among the normal forms, and were named by the author *Oenothera brevistylis* and *laevifolia*. Since that time these forms have maintained themselves, in spite of hybridization and the struggle for existence. From 1886 until now De Vries has made observations in the field at Hilversum, and has made almost innumerable cultures in the botanical garden at Amsterdam.

The experimental results may be briefly summarized. Out of 50,000 seedlings of *Oenothera Lamarckiana* in the various years of study, 800 or about 1.5 per cent., were mutants, while 98.5 per cent. came true to seed. Of these 800 mutants, more than one fourth belonged to the new species, *Oenothera lata, i. e.*, this species appeared anew in cultures more than 200 times; on the other hand *Oenothera gigas* appeared but once From a great many other new species the author selected the most promising for further study. The new species have proved to be quite distinct from one another and from the parent species, not only in one but in several characters. De Vries shows in an exhaustive and satisfactory fashion that his new forms are as fully entitled to specific rank as any of the Onagra group of Oenothera (*e. g.*, *O. biennis, Lamarckiana, muricata, cruciata*, etc.). Indeed, it is possible to identify most of the species with certainty, as early as the rosette stage, some species having round and others grasslike leaves. The mutations are planless, occurring in all possible directions, involving all plant organs. Some of the mutants appear to have improved upon the parent forms, but in most instances this is not the case. The great majority of the mutants are constant from the outset; there is no fixation of their characters by selection, nor is there any reversion. There are no transitions between parent and offspring. One extremely interesting result is that the mutants

themselves show occasional mutations, and in many cases the same species has arisen from different parents. There follow theoretical considerations which may be omitted here, except to state that De Vries believes in periodic mutability, since most species now appear to be immutable. What causes mutability can only be conjectured; perhaps it is favored by generations of excellent nutrition, perhaps by alternations of diverse conditions.

About half of the first volume deals more indirectly with mutation. One section treats of nutrition and selection, another with the origin of garden varieties, the author finding general agreement in a number of cases with his work on Oenothera.

Independently and all but simultaneously with De Vries, Korschinsky[2] has brought together a vast mass of data under the title *Heterogenesis and Evolution*. From the records of gardeners and horticulturists, he has attempted to show that most of the culture "varieties" have arisen through heterogenesis and not by means of selection. Such evidence is not very trustworthy in special cases, but perhaps the mass of detail by its mere quantity may help to strengthen the case as a whole. In any event such evidence and the fact that it is brought forward independently gives support to the work of De Vries. Solms-Laubach[3] has presented evidence to show that *Capsella Heegeri* has arisen as a sport from *C. Bursa-pastoris*. Carlson[4] thinks similarly for some Swedish forms of *Succisa pratensis*. C. A. White[5] reports cases of mutation in the Acme tomato. In a most admirable paper on the present condition of our knowledge as to the origin of species, Wettstein[6] holds that several theories are tenable, but that among them all that of heterogenesis seems most important. He gives some of his own observations in support of this theory. Moll,[7] in an extended and highly appreciative review of De Vries's work, says that this is easily the most important work on evolution since Darwin's *Origin of Species*. Schumann[8] holds that this is the first work that has really established the evolution theory; he also accepts the Jordan-De Vries concept of species and the system of trinomial nomenclature.

It is much too early, of course, to venture a final opinion as to the true value of this work. That it is one of the greatest of all contributions to the literature of evolution is certain. That it will lead to a flood of experimental investigation is assured, and perhaps this will be the author's greatest service to the world. Whether natural selection has had its day, whether mutation is the dominant method of the origin of species, and whether Jordan's "ele-

[2] Flora **89**: 240–363. 1901.

[3] Bot. Zeit. **58**[1]: 167–190. 1900.

[4] Bot. Not. **1901**: 224–226.

[5] Science **14**: 841–844. 1901.

[6] Ber. Deutsch. Bot. Ges. **18**: Generalversammlungsheft 184–200. 1900.

[7] Biol. Cent. **21**: 257–269; 289–305. 1901.

[8] Bot. Cent. **87**: 170. 1901.

mentary species" will replace the "collective species" of Linnaeus are questions that must be left for the future to answer.—H. C. COWLES.

MINOR NOTICES.

EDGAR W. OLIVE has[9] published a preliminary enumeration of the Sorophoreae, in advance of a more extended paper on the Acrasieae and their allies. Twenty-five species are presented, only one member of the group having been heretofore reported from America. A new genus (*Guttulinopsis*) is characterized, containing three species, and five other new species are described.—J. M. C.

THE FOURTH FASCICLE[10] of the list of the genera of seed plants according to the Engler sequence has just appeared. The general character of the work was stated in this journal[11] in the notice of the first fascicle. In the present signature 1340 genera are listed, bringing the total number up to 5182. This fascicle begins with Dipteryx (Leguminosae) and ends with Cochlanthera (Guttiferae).—J. M. C.

THE SEVENTH PART of Engler's *Pflanzenreich* has appeared,[12] and contains the Naiadaceae (family 12 of the spermatophyte series), by A. B. Rendle. The preliminary discussion is in English, and deals with the vegetative organs, anatomy, floral structure, geographic distribution, etc. The single genus *Naias* is presented as including thirty-two species, *N. marina* comprising sixteen named varieties.—J. M. C.

PARTS 211 and 212 of Engler and Prantl's *Natürlichen Pflanzenfamilien* have appeared.[12] The former contains the Lepidodendraceae, Bothrodendraceae, Sigillariaceae, and Pleuromoiaceae, by H. Potonié, and the beginning of Isoetaceae by R. Sadebeck. It is interesting to note that in Potonié's scheme of phylogeny the Lepidodendraceae give rise to the Araucarieae, and these in turn to the other conifers. Part 212 contains the Dicranaceae, Leucobryaceae, Fissidentaceae, Calymperaceae, and Pottiaceae by V. F. Brotherus.—J. M. C.

OHIO FUNGI EXSICCATI, briefly noticed last month, are being issued in small fascicles by Professor W. A. Kellerman, of the Ohio State University. They are not sold, but distributed to mycological students and collectors making exchanges. The first fascicle, issued November 20, 1901, contains sixteen numbers, the specimens being ample and well packeted. Eight of these numbers belong to the Uredineæ, and the remainder to various para-

[9] Proc. Amer. Acad. **37** : 333–344. 1901.

[10] DALLA TORRE, C. G. DE, and HARMS, A.: Genera Siphonogamarum ad systema Englerianum conscripta. Fasciculus quartus (signatura 31–40). Small 4to, pp. 241–320. Leipzig: Wilhelm Engelmann, 1901. *M* 4.

[11] BOT. GAZ. **30** : 67. 1900. [12] Press of Wilhelm Engelmann, Leipzig.

sitic micro-fungi. Beside the usual data on the labels some synonymy is given, and also the original description of the species *verbatim et literatum*. An entirely new feature of the distribution, and one to be commended highly, is the exact reproduction of the labels in the form of a journal article, to be distributed as separates. The first issue is in the *Ohio Naturalist* (**2**: 135–140) of last November. Beside the labels, there is a page of introductory matter.—J. C. ARTHUR.

THE *Bulletin de l'Herbier Boissier* has undertaken to publish a card index[13] of the new species appearing since January 1, 1901. The cards are intended to be intercalated with those published in this country by Miss Josephine E. Clark. Unfortunately they are printed in sheets upon thin paper and are perforated for separation. The light weight of the stock, the uneven size of the cards, and the ragged perforated edges will certainly prove exasperating to those who undertake to insert these among any standard series of cards. The data furnished will be extremely valuable, but we fear the form of the publication will nullify the laudable intentions of the editor. —C. R. B.

NOTES FOR STUDENTS.

GIOVANNOZZI has studied[14] the mechanism and functions of hygroscopic movements in plants. Among the topics treated are movements of floral bracts and anthers, leaf movements, opening and closing of fruits, torsion of awns, movements of the branches of conifers, dispersal of spores. Most commonly there is an unequal swelling of neighboring tissues, sclerenchymatous cells in particular possessing great capacity for taking up water.—H. C. COWLES.

DR. A. ZIMMERMANN has discovered in the "scattered, large, thickened, hard warts" described by Trimen in *Pavetta indica*, as well as in some other allied species of Rubiaceae, the presence of masses of bacteria which penetrate into intercellular spaces of the leaves while they are still very young and there develop into huge masses. The presence of these bacteria produces the wart. What are the relations between the two organisms remains for later experimental investigation.[15]—C. R. B.

MITOTIC PHENOMENA in the flagellate, Polytoma, are described by

[13] Index botanique universel des genres, espéces et variétés de plantes, parus depuis le 1er janvier 1901. Publié par le Bulletin de l'Herbier Boissier, Chambésy, suisse. 25 fr. par an. Suite à Index Kewensis. Ces fiches sont destinées à être intercalées avec les "Card-Index Clark" américaines.

[14] Nuov. Giorn. Bot. Ital. **8**: 207–237. 1901.

[15] ZIMMERMANN, A.: Ueber Bakterienknoten in den Blättern einiger Rubiaceen. Jahrb. Wiss. Bot. **37**: 1–12. *figs. 1–9.* 1901.

Prowazek.[16] Of special interest is his account of a nuclear centrosome somewhat similar to that described for Euglena and some other flagellates. A minute body makes its appearance in the nucleus, moves to the periphery, and is thrown out, surrounded by a clear area of protoplasm. The body then divides and the daughter centrosomes, taking position at opposite ends of the elongated nucleus, become the poles of the spindle.— B. M. DAVIS.

ITEMS OF TAXONOMIC INTEREST are as follows: CARL PURDY (Proc. Calif. Acad. Sci. III. Bot. **2**: 107–150 *pls. 15–19.* 1901) has published a revision of *Calochortus*, not including the Mexican species. He recognizes 40 species, describing 5 as new.—T. D. A. COCKERELL (Torreya **1**: 142–143. 1901) has proposed a new genus (*Hesperaster*) founded on *Bartonia decapetala* Sims (not the earlier *Bartonia* Muhl.) to include also certain species heretofore referred to *Mentzelia*. Under this new generic name 9 species are placed.—J. C. ARTHUR (Bull. Torr. Bot. Club **28**: 661–666. 1901) has begun a series of publications entitled "New species of Uredineae," the first installment containing 12.—ALICE EASTWOOD (*idem*, 667–674) in publishing some notes on Californian species of *Delphinium* has described 4 new species. —J. M. C.

J. W. MOLL[17] has devised an apparatus for focusing the projecting microscope from a distance. In order to give the demonstrator at the screen control over the focusing arrangement when very high magnification is desired, he arranged, after the object has been brought to approximate focus, to change the focus by sliding the ocular in and out. The ocular is fixed to a sliding block and is entirely independent of the part carrying the objective. A wire cord, attached to the front of the ocular carrier, passes around a pulley, thence over another pulley fixed to the ceiling, then to a wheel and axle arrangement near the screen. A cord with an adjustable handle is attached to the wheel. Two stout spiral springs in front of the ocular carrier return it into place when the tension of the cord is relaxed. The arrangement enables the demonstrator to control the focusing from any position near the screen.—W. J. G. LAND.

I. KOSIŃSKI has published in a recent number of Pringsheim's *Jahrbücher* a paper on the influence of various conditions on the respiration of *Aspergillus niger*.[18] It appears that when the fungus is deprived of food respiration very promptly diminishes. Growth is suspended at the same

[16] PROWAZEK: Kerntheilung und Vermehrung der Polytoma. Oester. Bot. Zeits. **51**: 51. 1901.

[17] Proc. Roy. Soc. Amsterdam **4**: 95–101. *1 pl.* 1901.

[18] I. KOSIŃSKI: Die Athmung bei Hungerzuständen und unter Einwirkung von mechanischen und chemischen Reizmitteln bei *Aspergillus niger*. Jahrb. Wiss. Bot. **37**: 137–204. 1901.

time, beginning again, with the increased respiration, upon the return of nutriment. A sudden increase in the concentration of the surrounding medium decreases the respiration, and *vice versa*. Severe mechanical injury accelerates respiration, as shown much better by Richards for phanerogams. Respiration is accelerated by the presence of zinc, iron, and manganese, cocaine, strychnine, and sufficiently dilute ether. The variation in the results (CO_2 evolved) from hour to hour is so excessive in many of the tables that if the conclusions should be called seriously in question they would be found supported here by very weak evidence.— E. B. COPELAND.

IKENO describes[19] conditions of spore formation in Taphrina that suggest the need of further studies of this type and other members of the Exoasceae. Two nuclei, present in the young ascus, unite to form a large nucleus characterized by a conspicuous nucleolous. The latter appears to be chromatic in character. The nuclear membrane shortly disappears and the chromatin body proceeds to fragment. Ikeno found no mitotic phenomena. The chromatin globules simply split up until a number are present in the cytoplasm. These small chromatin bodies then gather in groups in a common vacuole. Each body takes to it a certain amount of cytoplasm and a membrane formed around the whole completes a spore. The spores later multiply greatly by budding. It should be noted that Ikeno has failed to find here the process of spore formation described by Harper in the ascus, nor is there yet the progressive cleavage characteristic of the Phycomycetes.— B. M. DAVIS.

PART of the recent literature on the physiology of reproduction is summarized by Klebs[20] and utilized as the basis of an estimate of the most promising lines of work for the immediate future. The influence of light, transpiration, and various foods on the initiation of the reproductive processes have so far been found reasonably constant. But to justify generalization there is urgent need of a physiological study of reproduction in a considerable number of phanerogams. Conditions which do not directly affect the initiation of the reproductive processes may greatly influence their subsequent course. Growth and reproduction are in antagonism to the extent that either, under favorable conditions, demands all available plastic matter. The demands of growth on any external condition are less strict than those of reproduction. Klebs brings up more points in his condensed fifteen pages than can even be mentioned in a review—among them, the relation of heredity and environment as controlling factors; the interrelation of various modes of reproduction (a question of minor importance among higher plants); double fertilization and xenia. The possibility is pointed out, and it seems to the reviewer little short of a certainty, that we must yet recognize cases in

[19] IKENO: Spore formation in Taphrina. Flora **88**: 229. 1901.

[20] KLEBS, G.: Einige Ergebnisse der Fortpflanzungs-Physiologie. Ber. Deutsch. Bot. Gesells. **18**: 201–215. 1900.

which the hereditary character of the male gametes has an influence outside of either embryo or endosperm, in the seed coats and fruit.— E. B. COPELAND.

THE effect of various kinds of nutrition on the formation of enzymes has been carefully considered by Went in experiments on *Monilia sitophila*.[21] This fungus he had previously studied in Java and fully described in *Centralblatt für Bakteriologie* **72**: 1901, where also he discusses its culture in relation to different foods. It may develop ten different enzymes, all except trehalase formed in the culture fluid (though not all under like conditions), from which they may be precipitated by alcohol. They are malto-glucase (as Went prefers to name the enzyme which changes maltose into glucose), trehalase, raffinase, invertase, cytase, diastase, lipase, tyrosinase, lab enzyme, and trypsin. No retardation of the formation of the enzymes by the products of their activity could be observed in maltoglucase, invertase, diastase, or lipase.

The table below is an attempt to show diagrammatically the influence of the various materials upon enzyme development. More minute details as to the kinds of food tested must be sought in the paper itself. The sign + shows that the enzyme is formed with this food; the sign O, that it is not; –, that the case was not investigated.

	Casein	Peptone	Maltose	Raffinose	Glucose	Glycerin	Acetic acid
Lab enzyme	+	+	O	O	O	O	O
Trypsin	+	+	O	+?	O	O	O
Tyrosinase	+	+	+	+	+	+	+
Maltoglucase	+	+	+	+	O	O	O
Invertase	–	+	+	+?	+	+	+
Diastase	–	+	+	+	+	+	+

It is thus clear that in the same plant the different enzymes are affected differently by different foods. The danger of generalizing too widely from the few facts as yet ascertained is obvious. These experiments also help to do away with the idea, quite widely entertained, that enzyme development indicates a kind of starved condition of the cell. Usually it is only well nourished cells which develop much enzyme.— NINA G. HOLTON.

[21] WENT, F. A. F. C.: Ueber den Einfluss der Nahrung auf die Enzymbildung durch *Monilia sitophila* (Mont.) Sacc. Jahrb. Wiss. Bot. **36**: 611–664. 1901.

OPEN LETTERS.

THE ACTION OF FUNGICIDES.

IN DR. CLARK'S[1] paper, in a recent number of the BOTANICAL GAZETTE no attempt was made, as the author states, to discuss the literature of the subject; but Rumm[2] has written a paper that has such evident bearing on the subject that it should have received attention. The latter reached the following conclusion, based on experimental evidence closely resembling that adduced by Clark as indicating the solvent action on copper hydroxid of secretions or excretions from the cells: "Die Thatsachen, die uns Calcium und Kupferhydroxydmischungen ergeben haben, erklären sich leicht, wenn man annimmt, dass von Beginn der Einwirkung des Kupferhydroxyds an Spuren dieses Stoffes, welche durch aus den Algen austretende Säuren gelöst werden, wenigstens bis in die Wandsysteme der Algen vordringen und den Tod der letzteren bewirken." Rumm, however, failed to obtain the same results with Puccinia spores. It thus appears that the only difference between the explanation offered by Rumm and by Clark for the same phenomenon is that the former postulates an acid solvent excretion from the cell, while the latter has shown that saline or other organic substances probably produce the same effects.

Clark also failed to notice a short preliminary paper by the writer[3], in which are stated in outline results of investigation covering in substance every phase of the several factors affecting the action of fungicides on foliage which Clark mentions on page 44 of his paper, with the exception of the solvent action of the cell sap on copper hydroxid. The writer gave only part of the experimental data which he had obtained, but enough were given to substantiate the claim made here. A reference to the writer's paper will show the fact established that water must accompany copper hydrate or Bordeaux mixture on peach foliage in order to produce toxic effects.

[1] CLARK, JUDSON F.: On the toxic properties of some copper compounds, with special reference to Bordeaux mixture. BOT. GAZ. **33**: 26–48. 1902.

[2] RUMM, C.: Zur Kenntniss der Wirkung der Bordeauxbrühe und ihre Bestandteile auf Spirogyra longata und die Uredosporen von Puccinia coronata. Fünfstück's Beiträge **1**: 81–156. 1897. A preliminary announcement of results occurs in Ber. Deutsch. Bot. Gesells. **13**: 189–192. 1895, and another discussion of same experiments in Jahresh. Vereins vaterl. Naturk. Württemberg **54**: 322–327. 1898.

[3] BAIN, SAMUEL M., The injury of fungicides to peach foliage. Science N. S. **14**: 221, 222. 9 Ag 1901.

The writer also made an experiment on peach leaves quite similar to the one described by Clark, in order to determine whether the leaf gives off any substance having a solvent action on copper hydroxid, and obtained results similar to those obtained by Clark. But these data do not *per se* show the solution of copper hydroxid by leaves in general, because of the presence of gum in the sinuses of the teeth of the leaf in question, apparently secreted by the marginal glands. This gum remains, or is freshly secreted during most of the functional life of the leaf, and must evidently be taken into account in drawing conclusions from the experiment as made by Clark. There can be little doubt, however, that soluble substances escaping from leaves into water on their surfaces will influence the solvent action of this liquid on copper hydroxid. De Saussure found that washing leaves with distilled water removes a considerable proportion of the alkaline salts contained in them, and Gaudichaud and Sachs found that drops of water standing on leaves soon acquire an alkaline reaction towards litmus.

It appears that Barth[4] was first to propose the theory of the action of fungicides on foliage which was stated by Clark. Droop and Wortmann[5] are said to have disproved Barth's theory, but the writer has not yet had access to their publications.

In conclusion, the statement may be permitted that the writer does not underrate the importance of Dr. Clark's paper as a contribution to our knowledge of the fungicidal action of the Bordeaux mixture.—SAMUEL M. BAIN, *University of Tennessee, Knoxville.*

REJOINDER.

In regard to the foregoing criticism of the treatment of the literature in my paper, I call attention again to the fact, which Professor Bain recognizes, that no attempt was made "to review the literature of the subject."[6]

In regard to Bain's preliminary paper, I may add that my paper was completed and in the hands of the publishers some weeks before his paper appeared in *Science*. I may also point out that his paper was not concerned with the problem as to how the Bordeaux mixture *effects its mission as a fungicide* — the chief object of my investigation of Bordeaux mixture; and that in regard to the injurious effect frequently observed on the leaves of the host plant, which I discussed incidentally on page 44, I simply brought together those factors which seemed to me to be of importance in this connection, without doing any experimental work except on the solvent action of the cell sap on the copper hydroxid deposited on the leaves. Barth's suggestion has reference to the effect of the mixture on the host plant only.—JUDSON F. CLARK, *Cornell University.*

[4] Bot. Centralbl. **61**: 268, 269. 1895. [5] Zeits. Pflanzenkrankh. **10**: 165. 1901.

[6] CLARK, JUDSON F., BOT. GAZ. **33**: 26. 1902.

NEWS.

DR. FR. CZAPEK has been promoted to full professorship in the Imperial German University of Prague.

DR. CARL E. CRAMER, professor of botany in the Swiss Polytechnic Institute at Zurich, died November 24, 1901.

DR. FRIEDRICH KRASSER has been appointed associate professor of phytopaleontology in the Imperial University of Vienna.

DR. F. W. NEGER, privat-docent in the University at Munich, has been called to a professorship in the Forest Academy at Eisenach.

AMONG THE forthcoming publications of the Clarendon Press is an authorized translation of Schimper's *Pflanzengeographie*, by Percy Groom and W. R. Fisher.

MISS SUSAN M. HALLOWELL, professor of botany in Wellesley College, has resigned the active duties of the post, which she has held since 1875, and has been appointed professor emeritus.

DR. J. R. GREEN, professor of botany to the Pharmaceutical Society of Great Britain, and author of several important books, has been elected a fellow of Downing College, Cambridge.

M. J. COSTANTIN, maître de Conférences à l'École normale Supérieure, Paris, has been made Professeur de Culture at the Museum d'histoire naturelle, in place of M. Maxime Cornu, deceased.

DR. A. FISCHER, privat-docent in the University of Leipzig, has been called to Basel to fill the chair left vacant by the death of Professor A. F. W. Schimper. He will begin his work there in April.

DR. EDWARD B. COPELAND has been appointed instructor in botany in Leland Stanford University. He will spend the remainder of the year at the University of Chicago, assuming his new duties in the autumn.

THE *Victorian Naturalist* states that a monument erected in memory of Baron Sir F. von Mueller, for nearly forty-five years government botanist of Victoria, was unveiled in November 26 by the Governor General.

MESSRS. HENRY HOLT & CO. are just putting through the press a second edition of *A manual of the flora of the Northern States and Canada*, by Nathaniel Lord Britton, Director of the New York Botanical Garden.

LONGMANS, GREEN & CO. have in press an elementary plant physiology by Dr. D. T. MacDougal. The rights in his *Experimental Plant Physiology*,

published by Henry Holt & Co., have been purchased by Longmans, and the plates have been destroyed.

THE VENERABLE DR. J. B. JACK, the well-known student of the Hepaticae, died suddenly on August 14, 1901, in the 84th year of his age. His collection, exceedingly rich in the forms of European species, was purchased some time ago by the Boissier herbarium.

THE SALE of the *Botanisches Centralblatt* does not affect the status of the *Beihefte zum Botanisches Centralblatt*, which since January has been the property of Dr. O. Uhlworm, and will be continued under the joint editorship of Drs. Uhlworm and F. G. Kohl.

THE NEW *Bulletin de l'Herbier* of the botanical institute at Bucharest, published under the direction of Professor Vladesco, indicates an awakening along botanical lines in Roumania. The articles are published in Roumanian and in French or German in parallel columns.

PROFESSOR W. J. SPILLMAN, formerly of the Washington Agricultural Experiment Station, has been appointed agrostologist of the United States Department of Agriculture to succeed Mr. F. Lamson-Scribner, who is now chief of the Philippine Bureau of Agriculture.

ANOTHER VOLUME has appeared in Engler and Drude's monumental *Vegetation der Erde*, viz., an exhaustive treatise of the Illyrian region by Dr. Beck. This volume, together with an earlier one on the Caucasus region by Dr. Radde, will be reviewed in the next issue of this journal.

THE ANNOUNCEMENT of the fourth annual session of the University of Montana Biological Station at Flathead lake has been issued. The session lasts from July 14 to August 16; among the courses offered is one by Mr. Harry N. Whitford, assistant in botany at the University of Chicago. A number of lectures and excursions are planned.

WE NOTE from the *American Naturalist* the following items: Dr. Georg Bitter has been appointed docent for botany in the academy at Münster. Dr. Julius Stoklasa has been made professor of plant production in the Bohemian technical school at Prague. Dr. Hans Winkler has been made docent for botany at the University of Tübingen. J. R. Jackson, keeper of the Museum of Economic Botany, and George Nicholson, curator of the Kew Gardens, have retired.

ALFRED W. BENNETT died suddenly at his London home on January 23, in his 69th year. He was author of the monograph on Polygalaceae for Martius's *Flora Brasiliensis*, translator (with Dyer) of Sachs's *Text-book of botany*, author (with Murray) of an excellent *Handbook of cryptogamic botany*, and also of a highly popular *Flora of the Alps*, besides numerous short papers. For many years he has been one of the editors of the *Journal* of the Royal Microscopical Society.

FROM BUDAPEST comes a new journal, *Magyar Botanikai Lapok*, under the editorship of Dr. Degen Árpád, A. F. Károly and Thaisz Lajos. As Hungary was the only European state without an independent botanical journal, it seemed good to the founders to fill this gap. The declared objects of the journal are: (1) to supply a medium for the publication of notes on Hungarian botany, especially the floristic and systematic features; (2) to secure to Hungarians recognition for their botanical work by presenting it properly to the world; (3) to keep Hungarians better informed of foreign investigations. Articles in the first number appear in Latin or Magyar; in the latter case they are also printed in German.

A NEW ENGLISH BOTANICAL JOURNAL made its début in January. Announced as the British Botanical Journal, it appears as the *New Phytologist*, and is to be issued monthly except in August and September, under the editorship of Professor A. G. Tansley, of University College, London. It proposes to be "a medium of easy communication and discussion between British botanists on all botanical subjects, ... for announcing discoveries or theories, ... notices of important new books and papers, ... inquiries, ... or statements of difficulties on topics theoretical or practical." No doubt British botanists will welcome a journal of such general scope and we hope that it will receive generous support. The first number shows an intent to carry out the ideas set forth by the editor. Typographically the number is open to much improvement, particularly in the arrangement of the contents.

THE MINNESOTA SEASIDE STATION party of 1902 plans to leave Minneapolis on July 12, just at the close of the meeting of the National Educational Association. It will proceed via the Canadian Pacific Railway to Vancouver, thence by steamer to Victoria, where a stop of a day will be made, and finally to Port Renfrew on the straits of Juan de Fuca, B. C., by coasting vessel. The party will return to Minneapolis about September 1, giving a month or more by the sea, and ample time for stops in the Rockies and Selkirks. The following staff is expected to organize the work of instruction and research: Conway MacMillan, of the University of Minnesota, director and lecturer on algology (Phaeophyceae); Raymond Osburn, of the University of Ohio, professor of zoology; K. Yendo, of the Imperial University of Tōkyō, professor of algology (Rhodophyceae); and Miss Josephine E. Tilden, of the University of Minnesota, professor of algology (Chlorophyceae and Cyanophyceae).